US009439198B2

(12) **United States Patent**
Inoue et al.

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(45) **Date of Patent: Sep. 6, 2016**

(54) **RADIO BASE STATION, RADIO COMMUNICATION SYSTEM AND RADIO COMMUNICATION METHOD**

(71) Applicant: **NTT DOCOMO, INC.**, Tokyo (JP)

(72) Inventors: **Yuki Inoue**, Tokyo (JP); **Satoshi Nagata**, Tokyo (JP); **Takehiro Nakamura**, Tokyo (JP)

(73) Assignee: **NTT DOCOMO, INC.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 31 days.

(21) Appl. No.: **14/387,383**

(22) PCT Filed: **Feb. 8, 2013**

(86) PCT No.: **PCT/JP2013/053031**
§ 371 (c)(1),
(2) Date: **Sep. 23, 2014**

(87) PCT Pub. No.: **WO2013/145885**
PCT Pub. Date: **Oct. 3, 2013**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

Mar. 30, 2012 (JP) 2012-081085

(51) **Int. Cl.**
H04W 72/00 (2009.01)
H04W 72/04 (2009.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04W 72/046*** (2013.01); ***H04B 7/0615*** (2013.01); ***H04B 7/0697*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H04W 72/04
USPC 455/452.1
See application file for complete search history.

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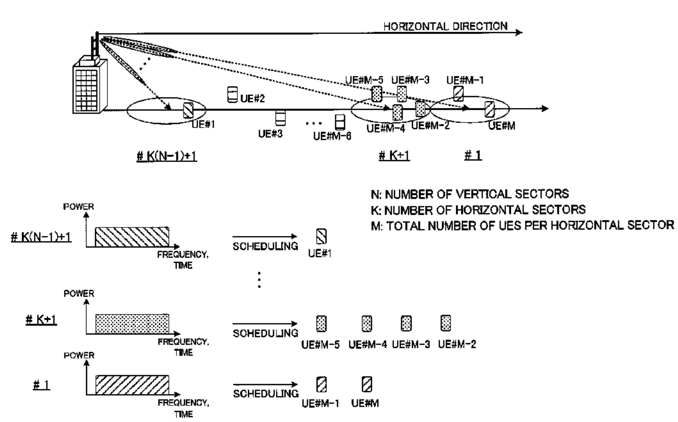
Primary Examiner — Santiago Garcia
(74) *Attorney, Agent, or Firm* — Osha Liang LLP

(57) **ABSTRACT**

The present invention is designed to make effective use of radio resources in VSEC to output a plurality of beams of varying tilt angles for sectorization in vertical directions. A radio communication method for a radio base station that outputs a plurality of beams of varying tilt angles and forms a plurality of cells that are sectorized vertically, and a user terminal that establishes wireless connection with the radio base station, provides the steps in which the radio base station acquires information about the communication capacity of each of the plurality of cells, and controls the vertical plane beam width and/or transmission power of each cell and sets the coverage area of each cell so that differences in communication capacity between the plurality of cells are reduced.

4 Claims, 23 Drawing Sheets



(51) **Int. Cl.**

H04W 16/28	(2009.01)
H04B 7/06	(2006.01)
H04W 52/14	(2009.01)
H04W 52/34	(2009.01)
H04W 16/08	(2009.01)
H04W 16/30	(2009.01)
H04W 52/42	(2009.01)
H04W 88/08	(2009.01)

(52) **U.S. Cl.**

CPC ***H04W 16/28*** (2013.01); ***H04W 52/143*** (2013.01); ***H04W 52/343*** (2013.01); ***H04W 72/0446*** (2013.01); ***H04W 72/0486*** (2013.01); *H04W 16/08* (2013.01); *H04W 16/30* (2013.01); *H04W 52/42* (2013.01); *H04W 88/08* (2013.01)

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O. Yilmaz et al.; "System Level Analysis of Vertical Sectorization for 3GPP LTE;" IEEE; Department of Communications and Networking, Helsinki University of Technology; Espoo, Finland; 2009; pp. 453-457 (5 pages).

Office Action in counterpart Japanese Patent Application No. 2012-081085 issued on Mar. 29, 2016 (8 pages).

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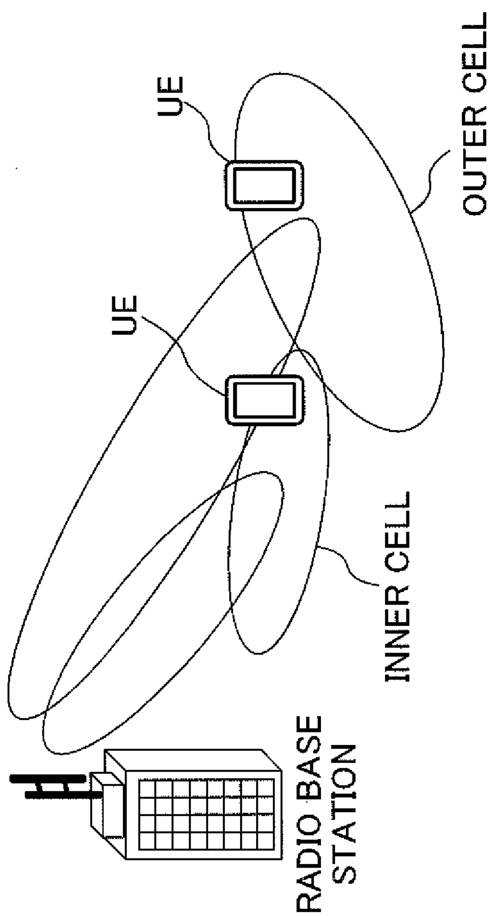


FIG.1A

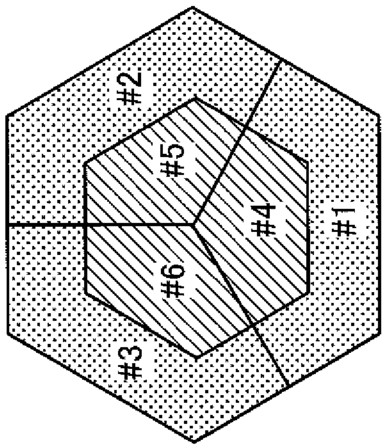


FIG.1B

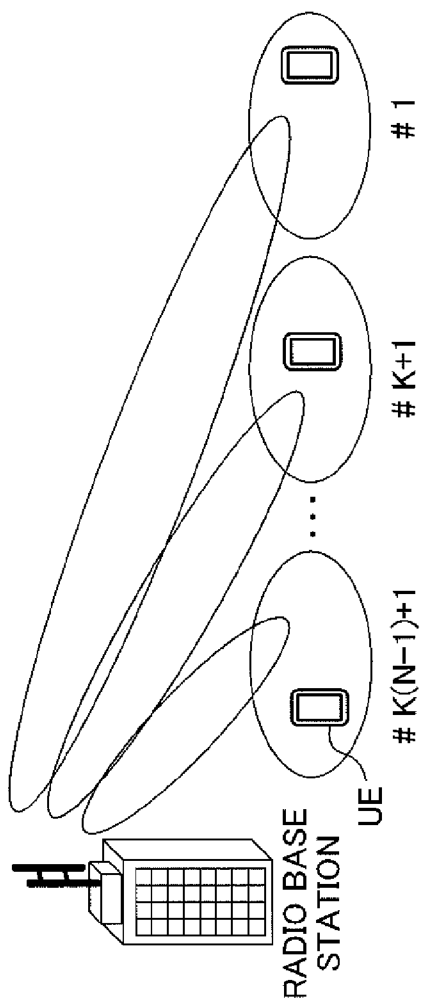

RADIO BASE STATION
UE
K(N−1)+1
K+1
1

FIG.2A

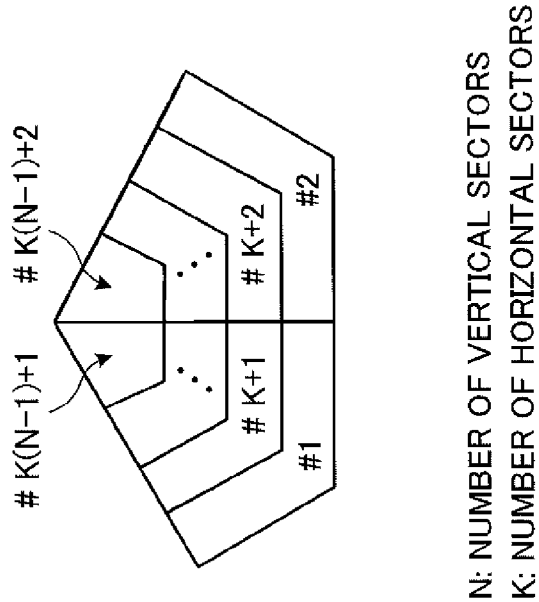

K(N−1)+1
K(N−1)+2
K+1
K+2
#1
#2
N: NUMBER OF VERTICAL SECTORS
K: NUMBER OF HORIZONTAL SECTORS

FIG.2B

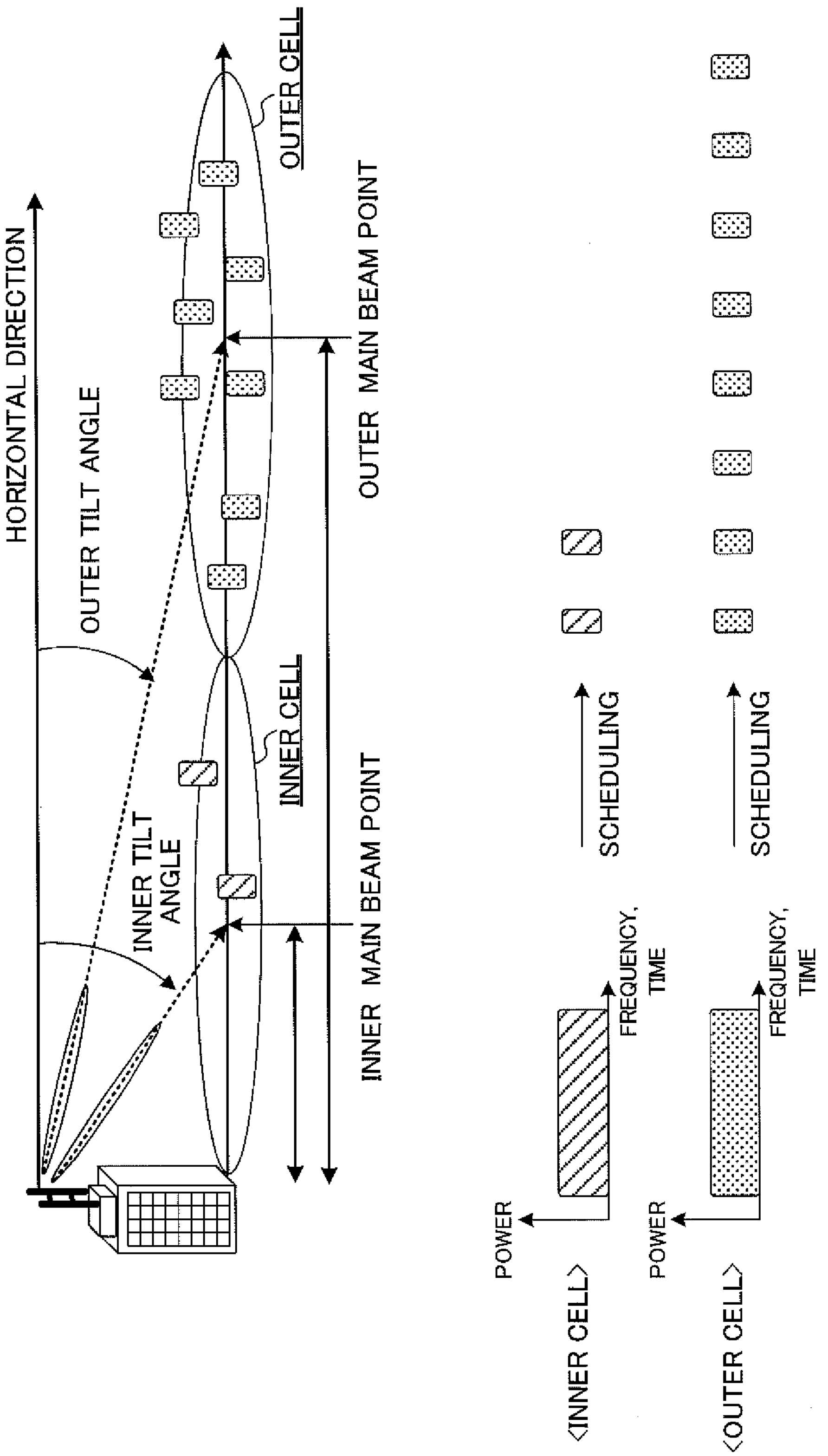
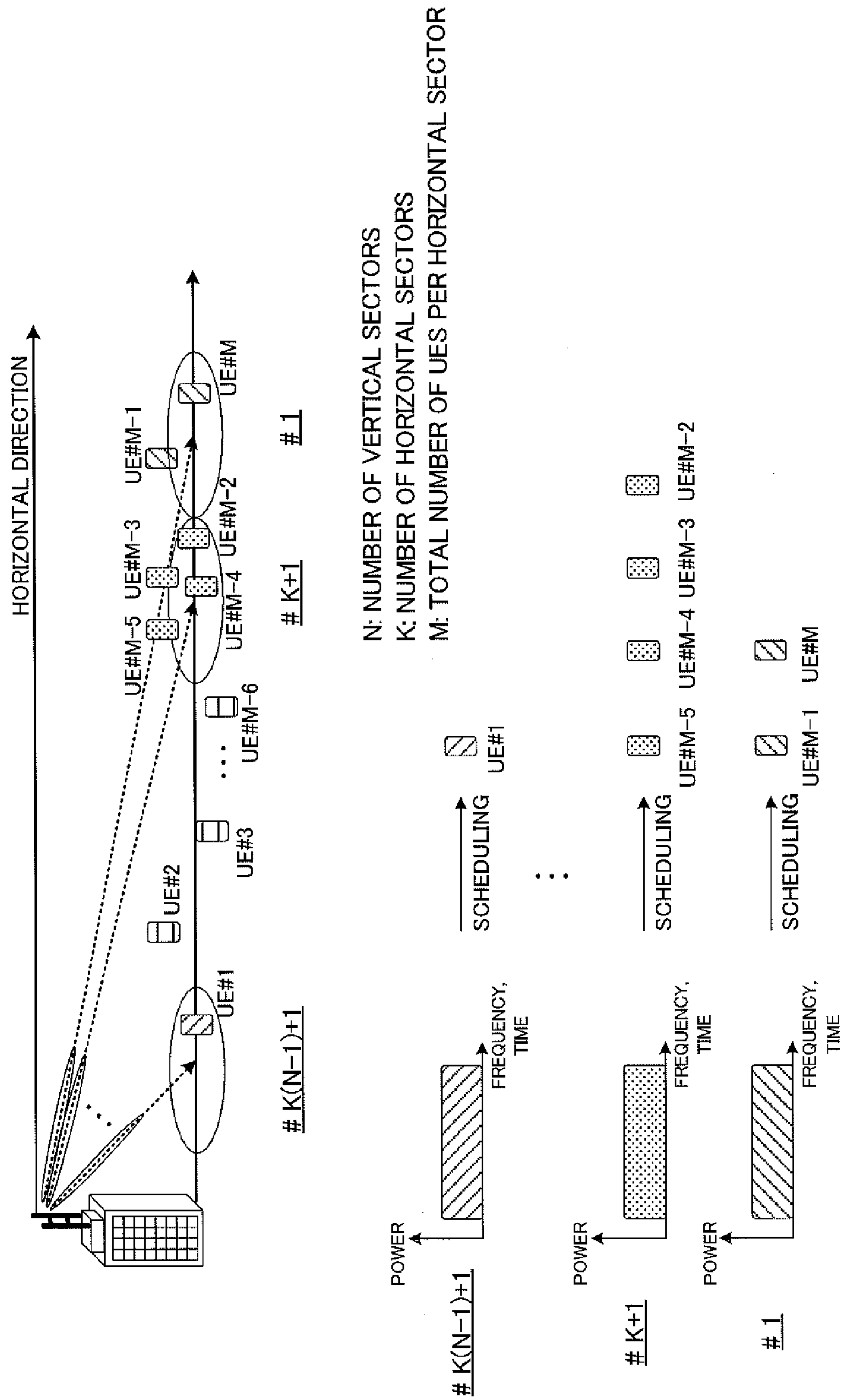
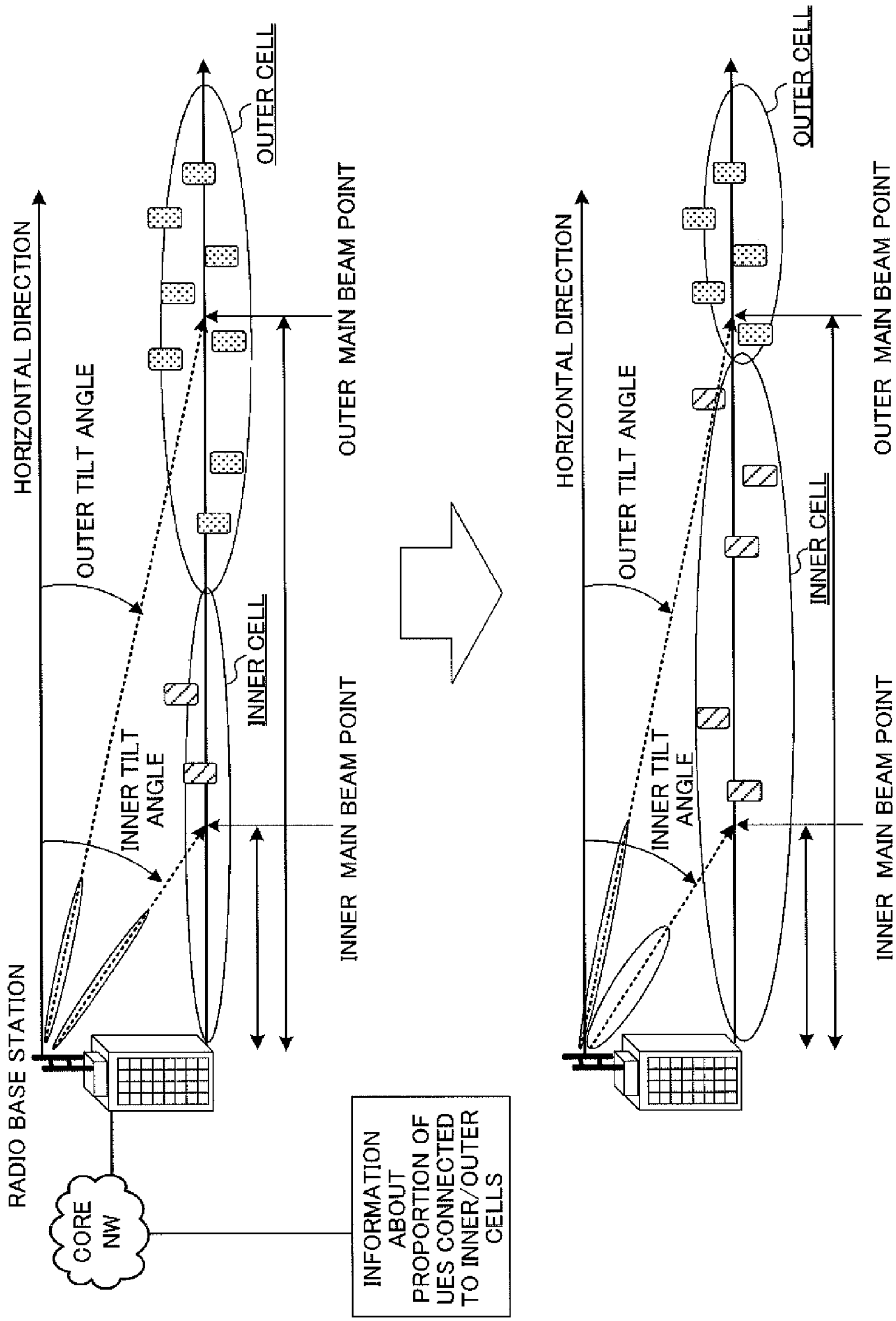

HORIZONTAL DIRECTION
OUTER TILT ANGLE
INNER TILT ANGLE
OUTER CELL
INNER CELL
OUTER MAIN BEAM POINT
INNER MAIN BEAM POINT
<INNER CELL>
POWER
FREQUENCY, TIME
SCHEDULING
<OUTER CELL>
POWER
FREQUENCY, TIME
SCHEDULING

FIG.3



HORIZONTAL DIRECTION
UE#1
UE#2
UE#3
UE#M-6
UE#M-5
UE#M-4
UE#M-3
UE#M-2
UE#M-1
UE#M
K(N-1)+1
K+1
1
N: NUMBER OF VERTICAL SECTORS
K: NUMBER OF HORIZONTAL SECTORS
M: TOTAL NUMBER OF UES PER HORIZONTAL SECTOR
K(N-1)+1
POWER
FREQUENCY, TIME
SCHEDULING
UE#1
K+1
POWER
FREQUENCY, TIME
SCHEDULING
UE#M-5
UE#M-4
UE#M-3
UE#M-2
1
POWER
FREQUENCY, TIME
SCHEDULING
UE#M-1
UE#M

FIG.4



RADIO BASE STATION
CORE NW
INFORMATION ABOUT PROPORTION OF UES CONNECTED TO INNER/OUTER CELLS
HORIZONTAL DIRECTION
OUTER TILT ANGLE
INNER TILT ANGLE
OUTER CELL
INNER CELL
OUTER MAIN BEAM POINT
INNER MAIN BEAM POINT
HORIZONTAL DIRECTION
OUTER TILT ANGLE
INNER TILT ANGLE
OUTER CELL
INNER CELL
OUTER MAIN BEAM POINT
INNER MAIN BEAM POINT

FIG.5

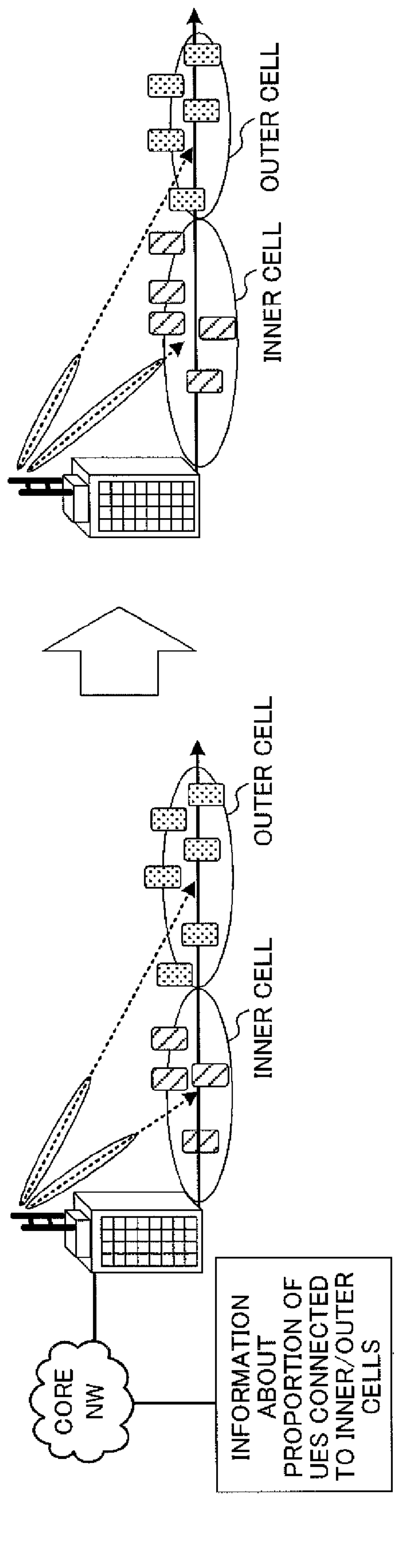

OUTER CELL
INNER CELL
OUTER CELL
INNER CELL
CORE NW
INFORMATION ABOUT PROPORTION OF UES CONNECTED TO INNER/OUTER CELLS

FIG.6

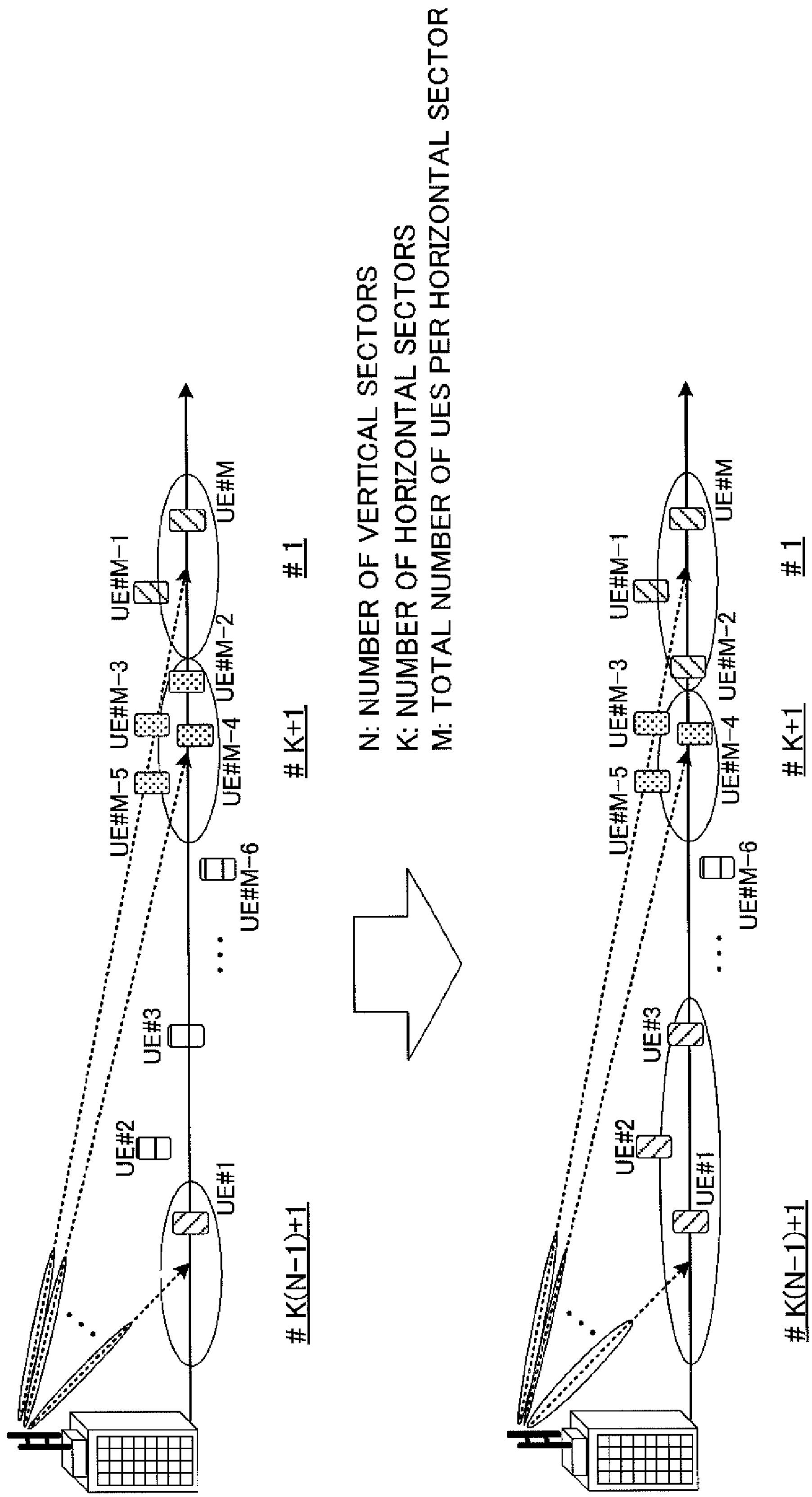

UE#1
UE#2
UE#3
UE#M-6
UE#M-5
UE#M-4
UE#M-3
UE#M-2
UE#M-1
UE#M
K(N-1)+1
K+1
1
N: NUMBER OF VERTICAL SECTORS
K: NUMBER OF HORIZONTAL SECTORS
M: TOTAL NUMBER OF UES PER HORIZONTAL SECTOR

FIG.7

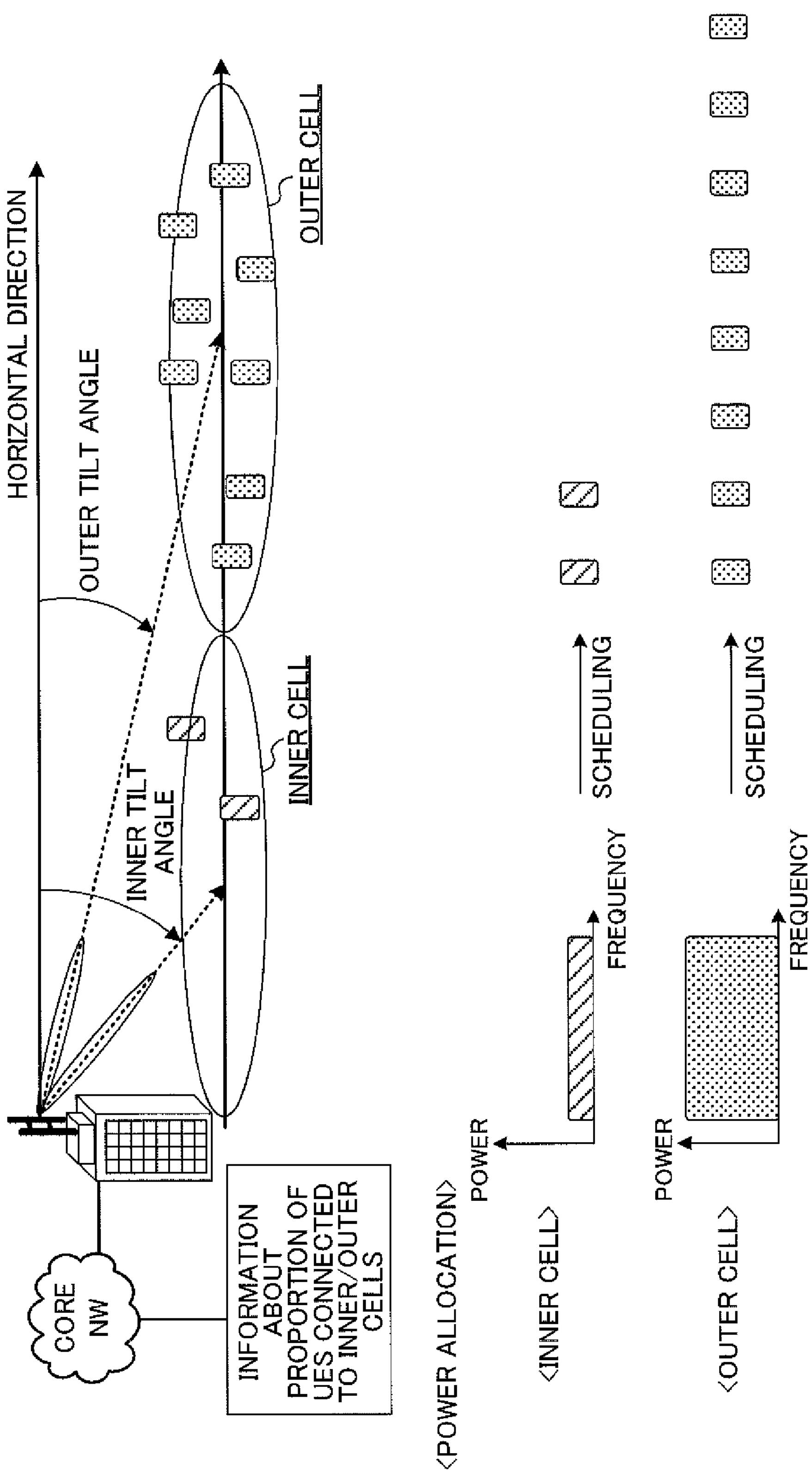
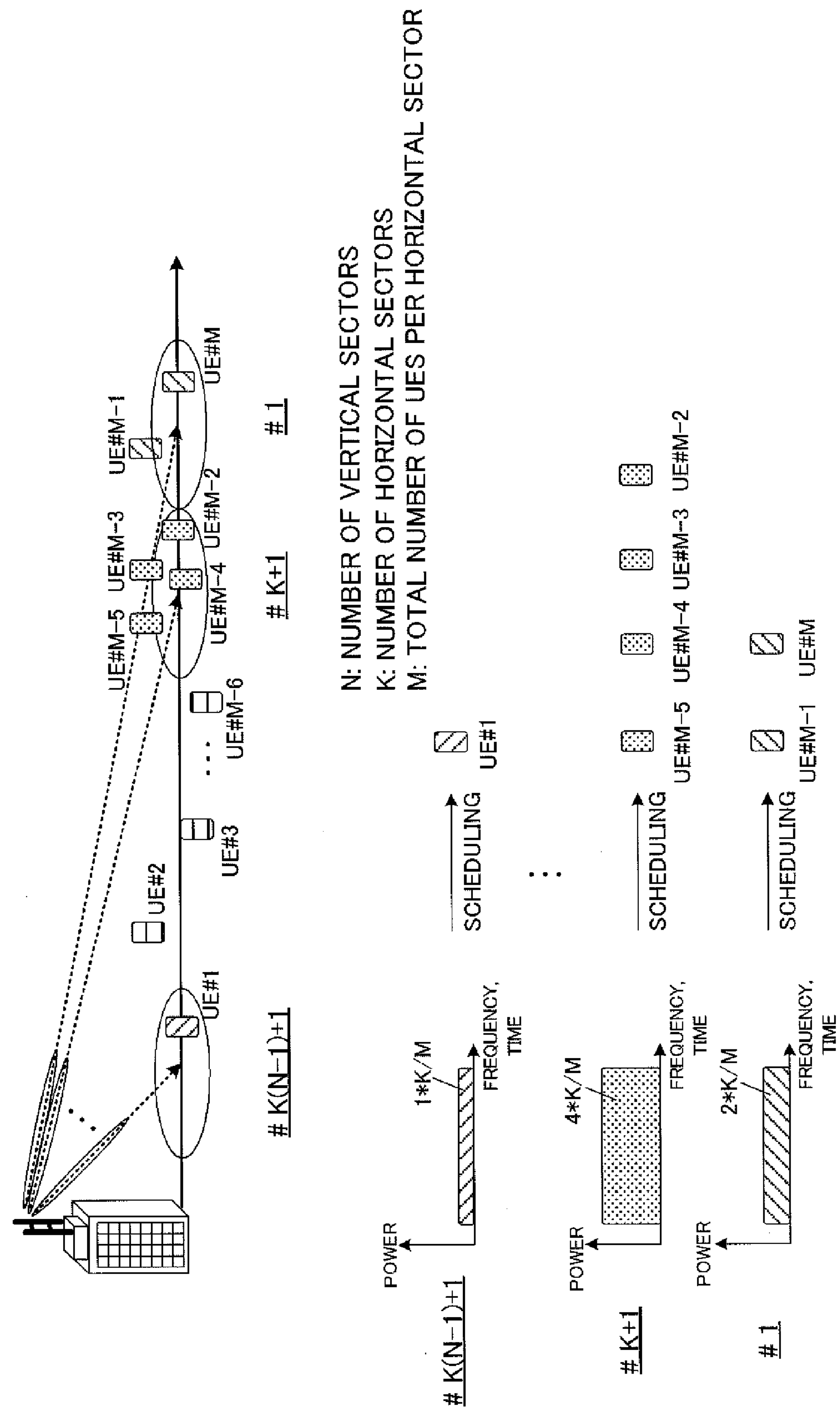

HORIZONTAL DIRECTION
OUTER TILT ANGLE
INNER TILT ANGLE
OUTER CELL
INNER CELL
CORE NW
INFORMATION ABOUT PROPORTION OF UES CONNECTED TO INNER/OUTER CELLS
〈POWER ALLOCATION〉
〈INNER CELL〉
〈OUTER CELL〉
POWER
FREQUENCY
SCHEDULING
POWER
FREQUENCY
SCHEDULING

FIG.8



UE#1
UE#2
UE#3
UE#M−6
UE#M−5
UE#M−4
UE#M−3
UE#M−2
UE#M−1
UE#M
K(N−1)+1
K+1
1
N: NUMBER OF VERTICAL SECTORS
K: NUMBER OF HORIZONTAL SECTORS
M: TOTAL NUMBER OF UES PER HORIZONTAL SECTOR
K(N−1)+1
POWER
1*K/M
FREQUENCY, TIME
SCHEDULING
UE#1
K+1
POWER
4*K/M
FREQUENCY, TIME
SCHEDULING
UE#M−5
UE#M−4
UE#M−3
UE#M−2
1
POWER
2*K/M
FREQUENCY, TIME
SCHEDULING
UE#M−1
UE#M

FIG.9

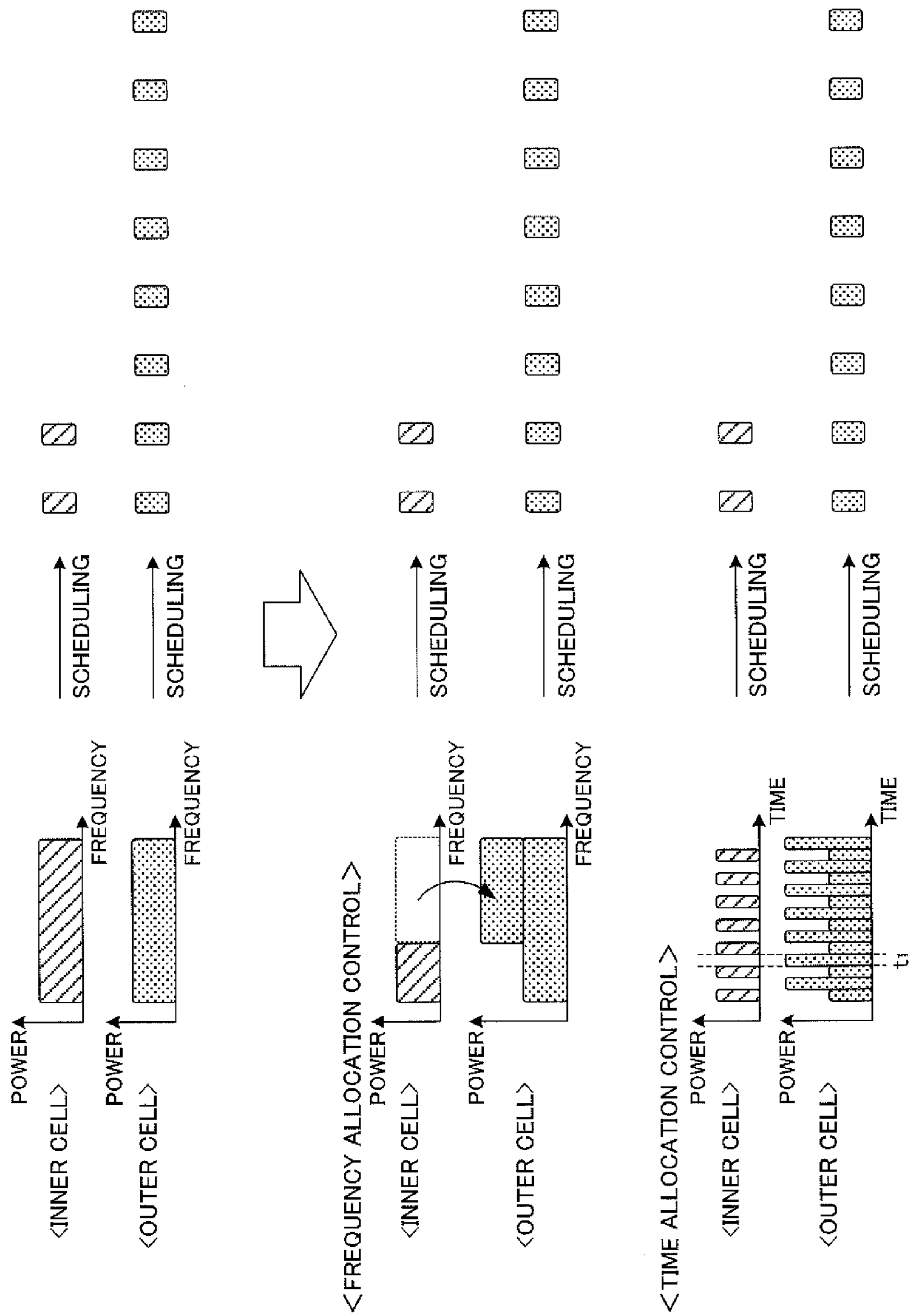
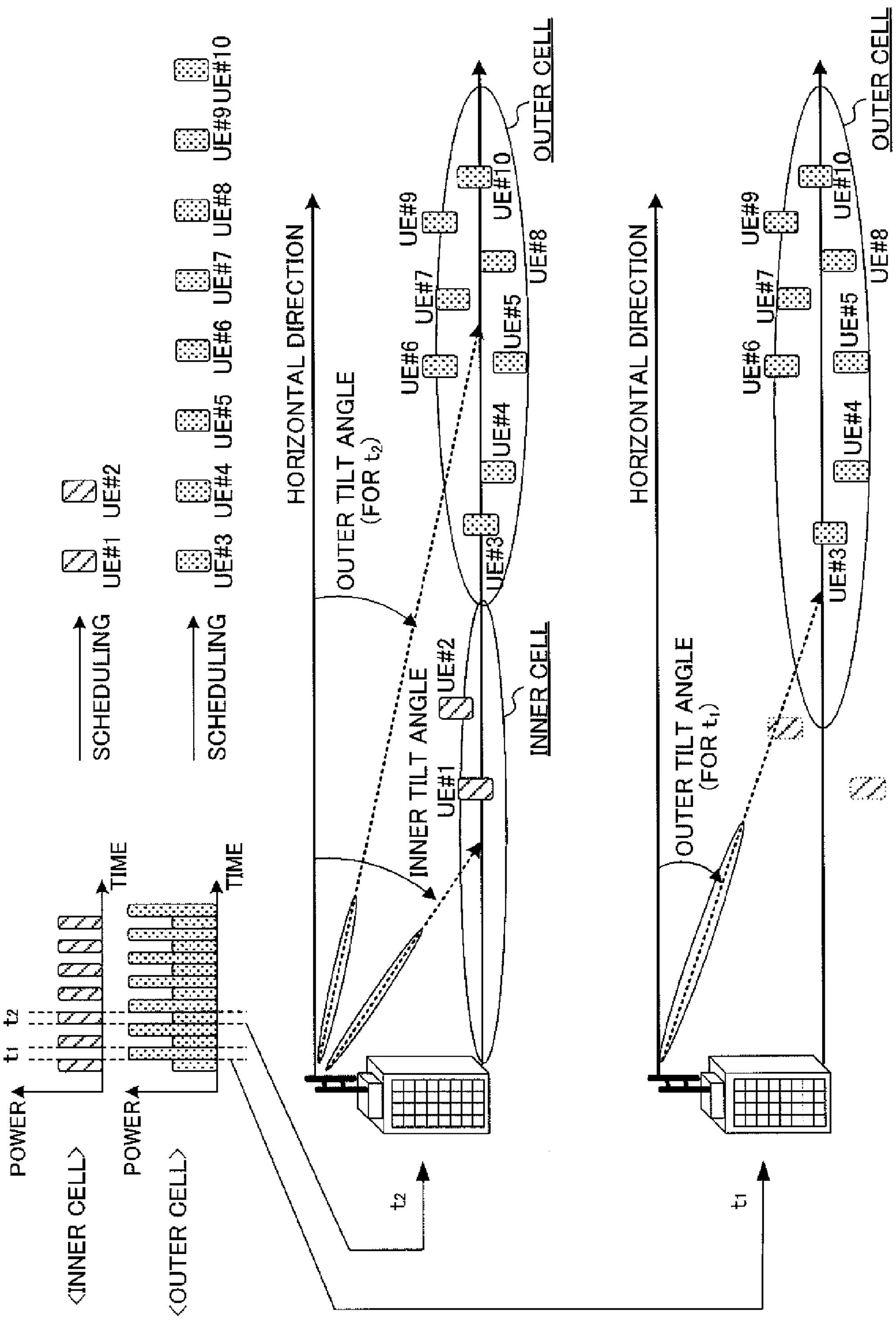


FIG.10A

FIG.10B

FIG.10C



<INNER CELL>
POWER
TIME
t1
t2
SCHEDULING
UE#1
UE#2
<OUTER CELL>
POWER
TIME
SCHEDULING
UE#3
UE#4
UE#5
UE#6
UE#7
UE#8
UE#9
UE#10
t2
HORIZONTAL DIRECTION
OUTER TILT ANGLE (FOR t_2)
INNER TILT ANGLE
INNER CELL
OUTER CELL
t1
OUTER TILT ANGLE (FOR t_1)

FIG.11

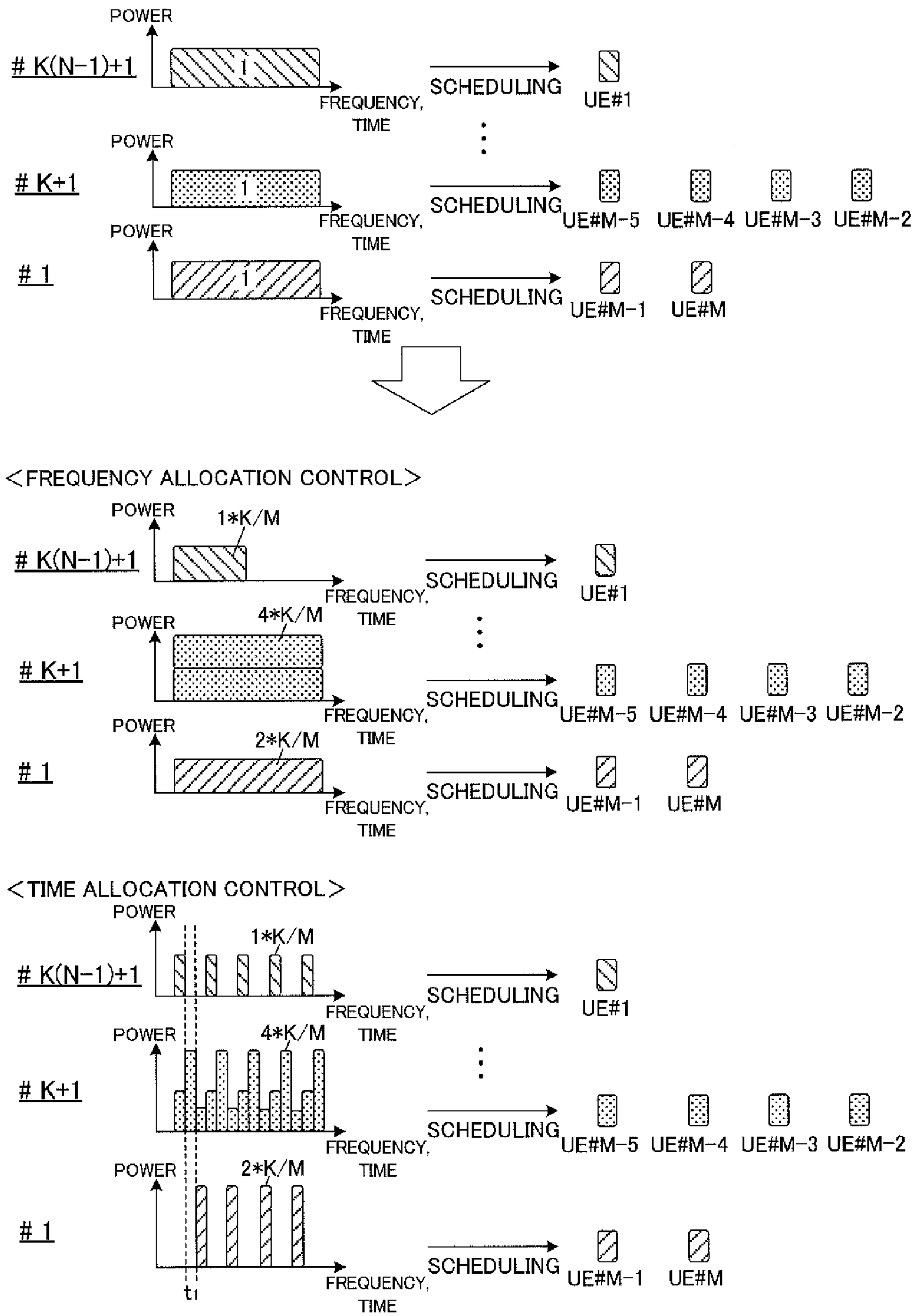

POWER
K(N-1)+1
1
FREQUENCY, TIME
SCHEDULING
UE#1
POWER
K+1
1
FREQUENCY, TIME
SCHEDULING
UE#M-5 UE#M-4 UE#M-3 UE#M-2
POWER
1
1
FREQUENCY, TIME
SCHEDULING
UE#M-1 UE#M
<FREQUENCY ALLOCATION CONTROL>
POWER
1*K/M
K(N-1)+1
FREQUENCY, TIME
SCHEDULING
UE#1
POWER
4*K/M
K+1
FREQUENCY, TIME
SCHEDULING
UE#M-5 UE#M-4 UE#M-3 UE#M-2
POWER
2*K/M
1
FREQUENCY, TIME
SCHEDULING
UE#M-1 UE#M
<TIME ALLOCATION CONTROL>
POWER
1*K/M
K(N-1)+1
FREQUENCY, TIME
SCHEDULING
UE#1
POWER
4*K/M
K+1
FREQUENCY, TIME
SCHEDULING
UE#M-5 UE#M-4 UE#M-3 UE#M-2
POWER
2*K/M
1
t1
FREQUENCY, TIME
SCHEDULING
UE#M-1 UE#M

FIG.12

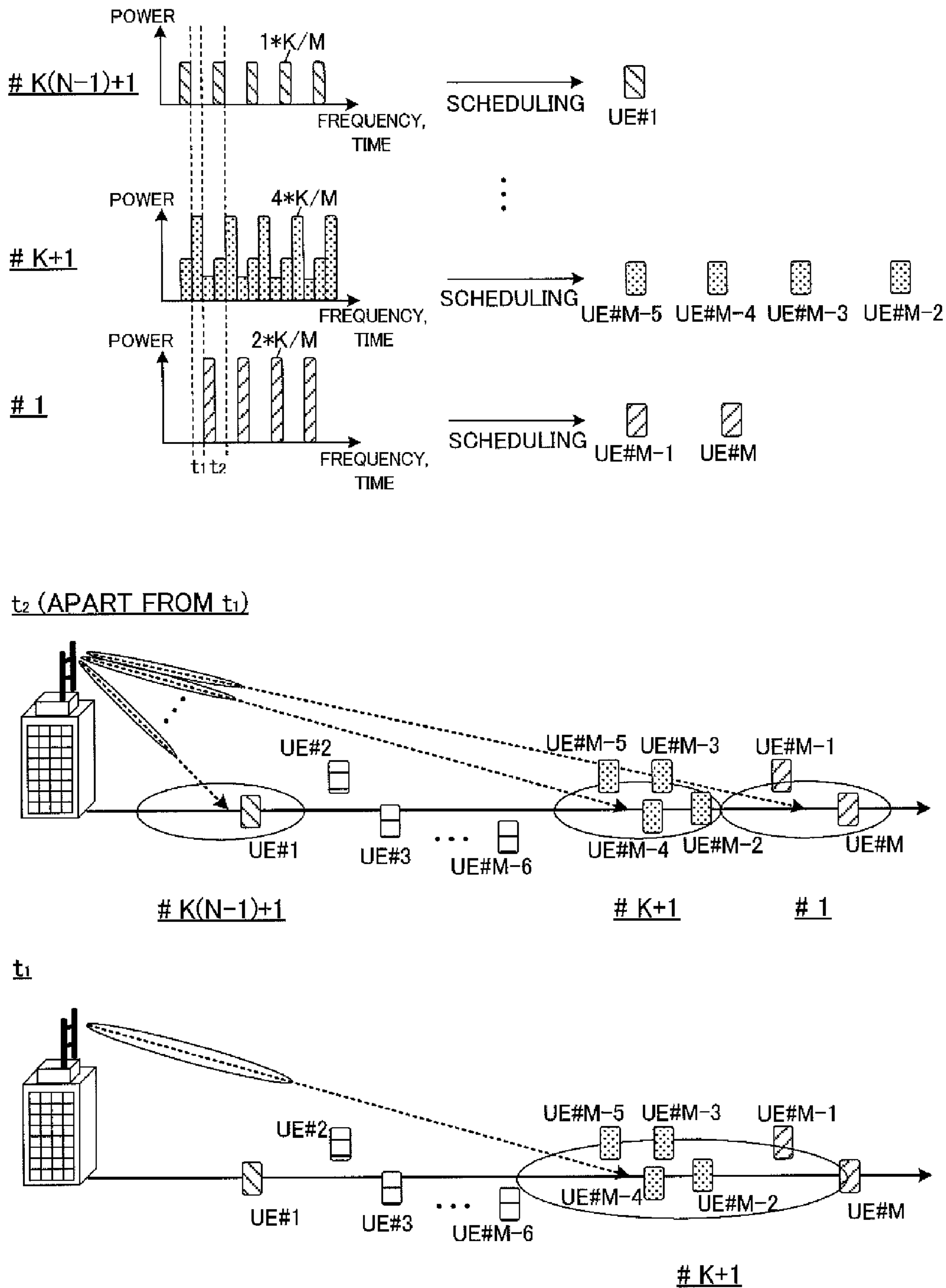
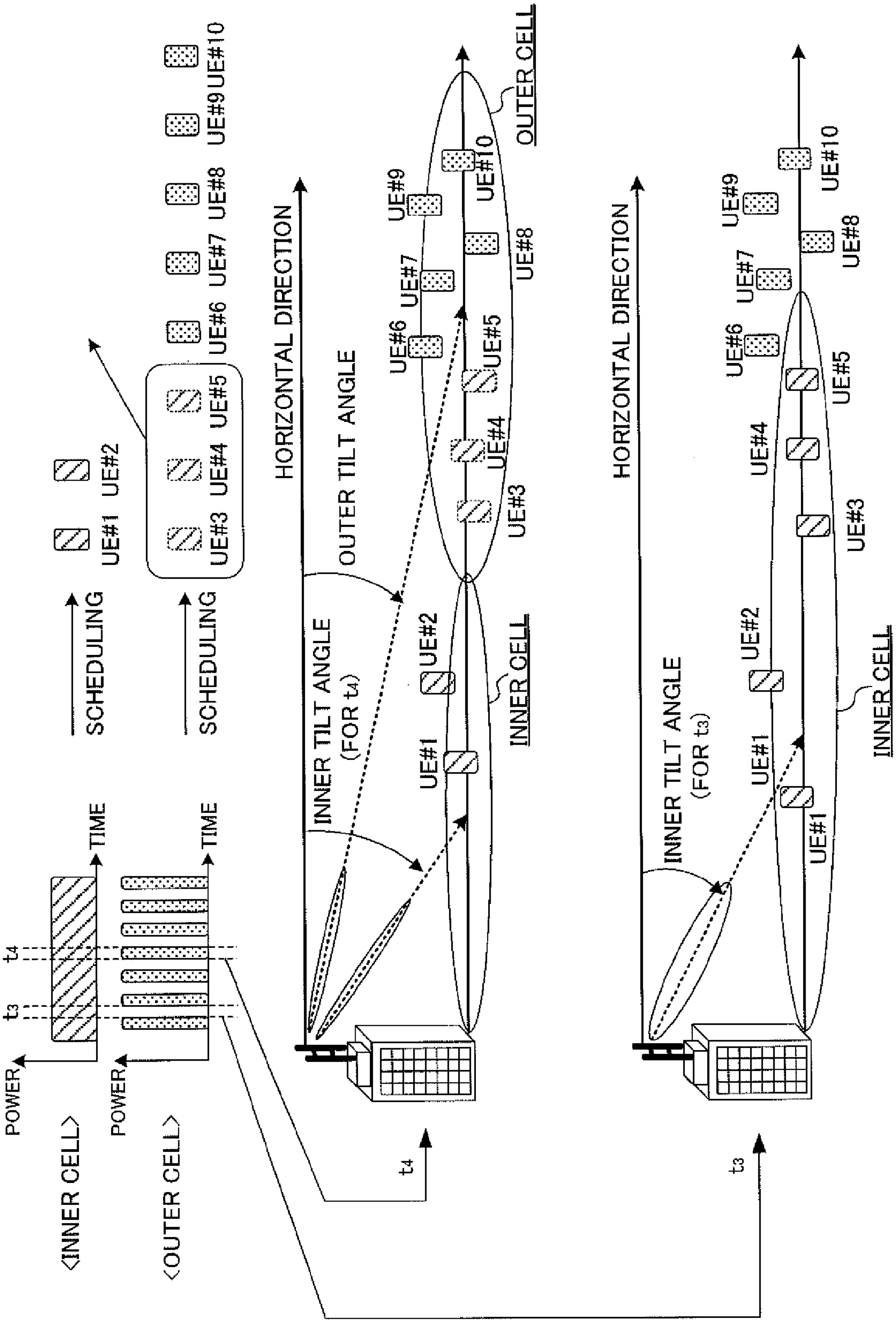

POWER
1*K/M
K(N−1)+1
FREQUENCY, TIME
SCHEDULING
UE#1
POWER
4*K/M
K+1
FREQUENCY, TIME
SCHEDULING
UE#M−5
UE#M−4
UE#M−3
UE#M−2
POWER
2*K/M
1
FREQUENCY, TIME
SCHEDULING
UE#M−1
UE#M
t1 t2
t2 (APART FROM t1)
UE#2
UE#M−5
UE#M−3
UE#M−1
UE#1
UE#3
UE#M−6
UE#M−4
UE#M−2
UE#M
K(N−1)+1
K+1
1
t1
UE#2
UE#M−5
UE#M−3
UE#M−1
UE#1
UE#3
UE#M−6
UE#M−4
UE#M−2
UE#M
K+1

FIG.13



〈INNER CELL〉
POWER
TIME
t3
t4
SCHEDULING
UE#1
UE#2
〈OUTER CELL〉
POWER
TIME
SCHEDULING
UE#3
UE#4
UE#5
UE#6
UE#7
UE#8
UE#9
UE#10
HORIZONTAL DIRECTION
OUTER TILT ANGLE
INNER TILT ANGLE
(FOR t4)
INNER CELL
OUTER CELL
t4
HORIZONTAL DIRECTION
INNER TILT ANGLE
(FOR t3)
INNER CELL
t3

FIG.14

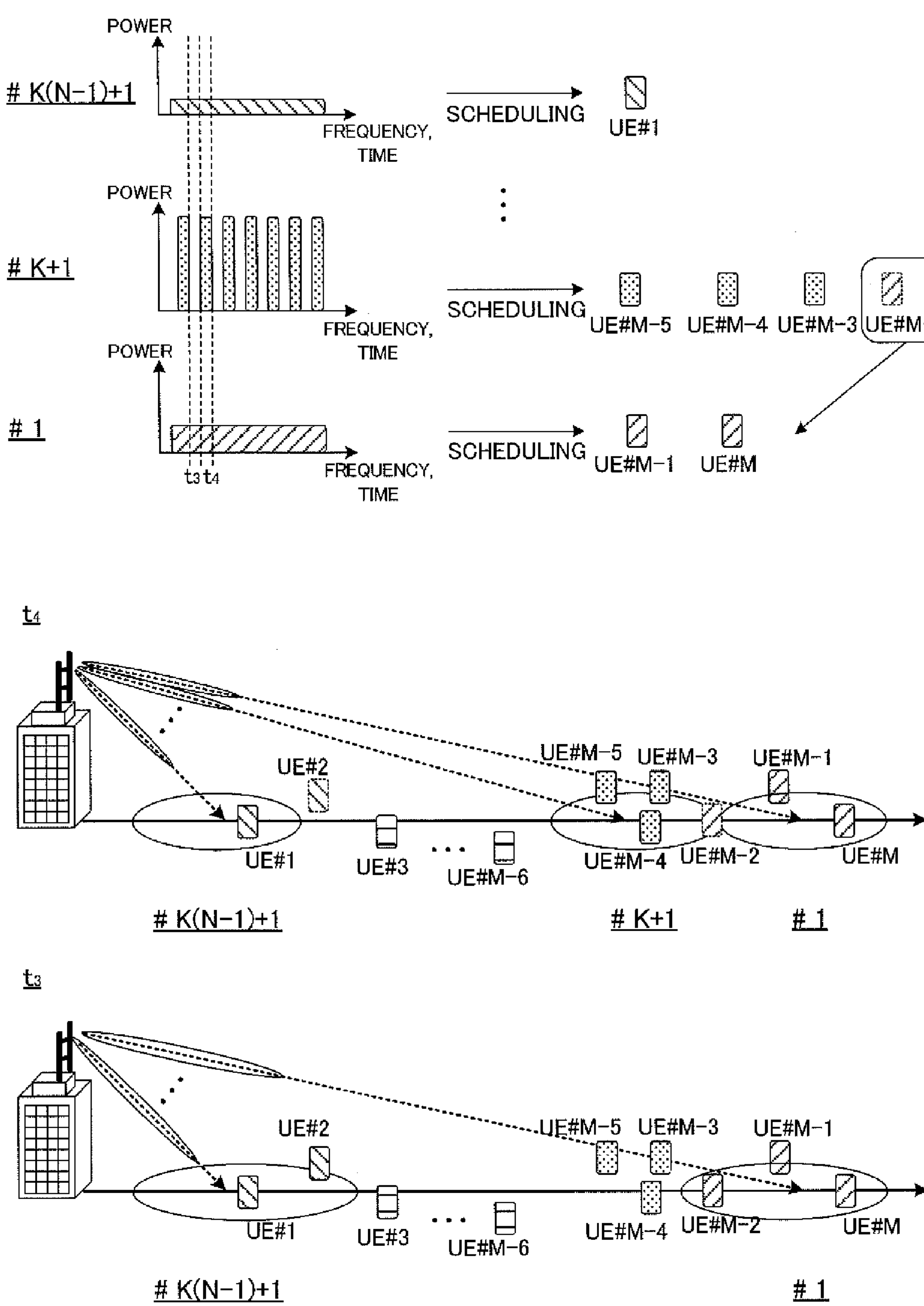

POWER
K(N−1)+1
FREQUENCY, TIME
SCHEDULING
UE#1
POWER
K+1
FREQUENCY, TIME
SCHEDULING
UE#M−5
UE#M−4
UE#M−3
UE#M−2
POWER
1
FREQUENCY, TIME
SCHEDULING
UE#M−1
UE#M
t3 t4
t4
UE#2
UE#M−5
UE#M−3
UE#M−1
UE#1
UE#3
UE#M−6
UE#M−4
UE#M−2
UE#M
K(N−1)+1
K+1
1
t3
UE#2
UE#M−5
UE#M−3
UE#M−1
UE#1
UE#3
UE#M−6
UE#M−4
UE#M−2
UE#M
K(N−1)+1
1

FIG.15

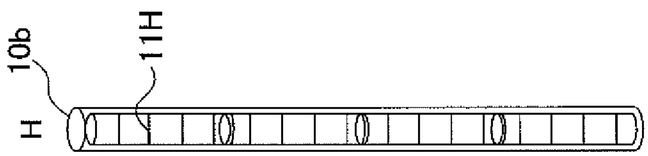


FIG.16C

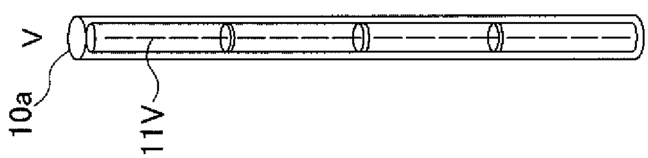


FIG.16B

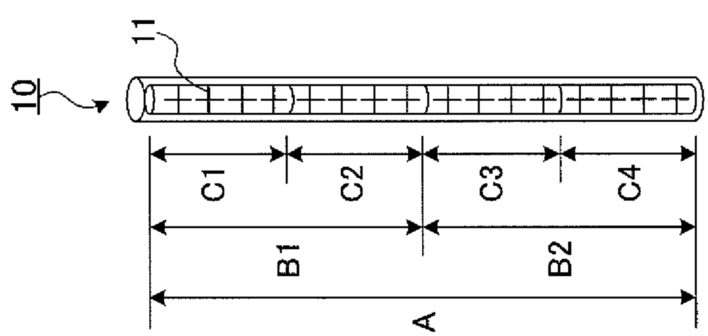


FIG.16A

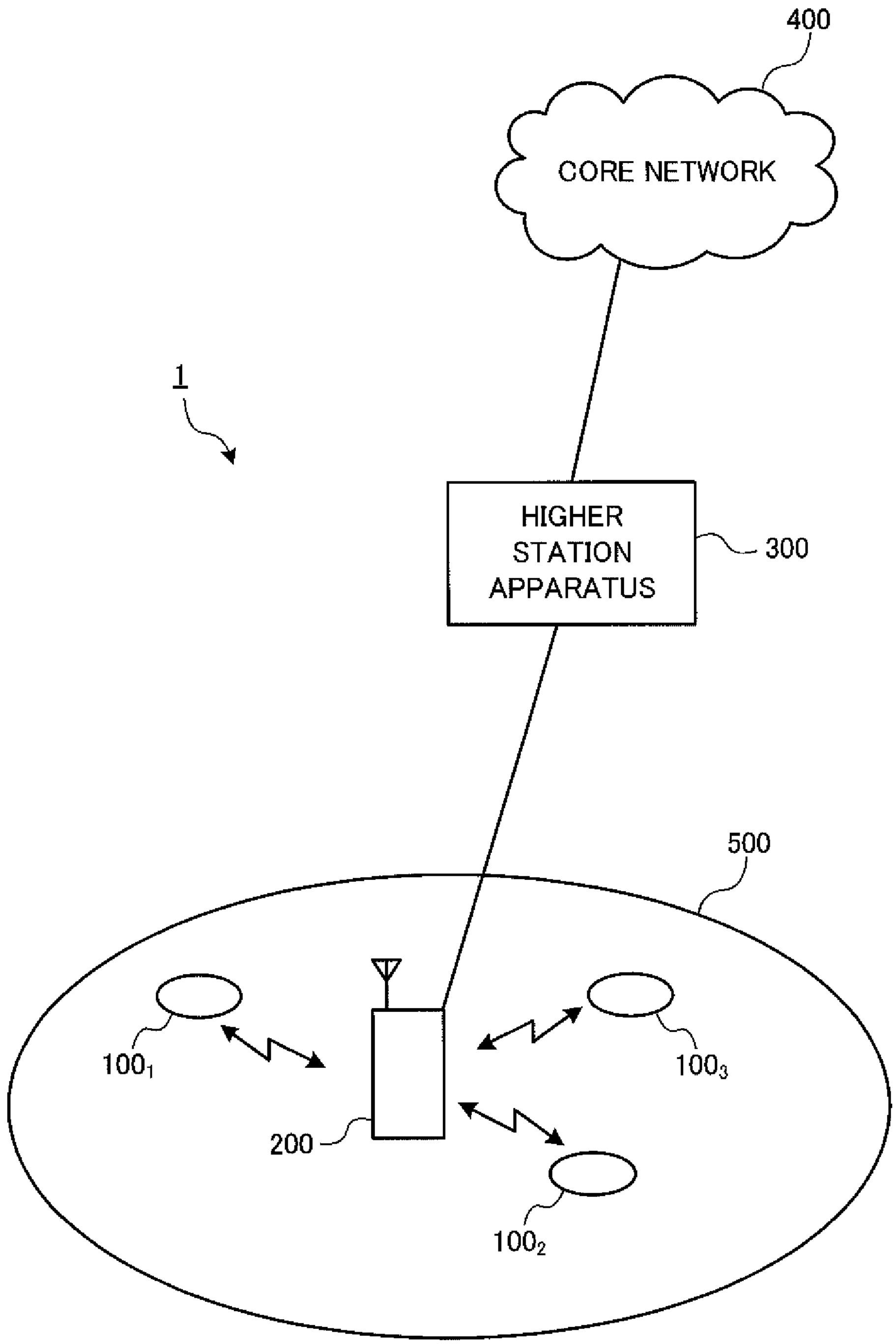

400
CORE NETWORK
1
HIGHER STATION APPARATUS
300
500
100_1
100_3
200
100_2

FIG.17

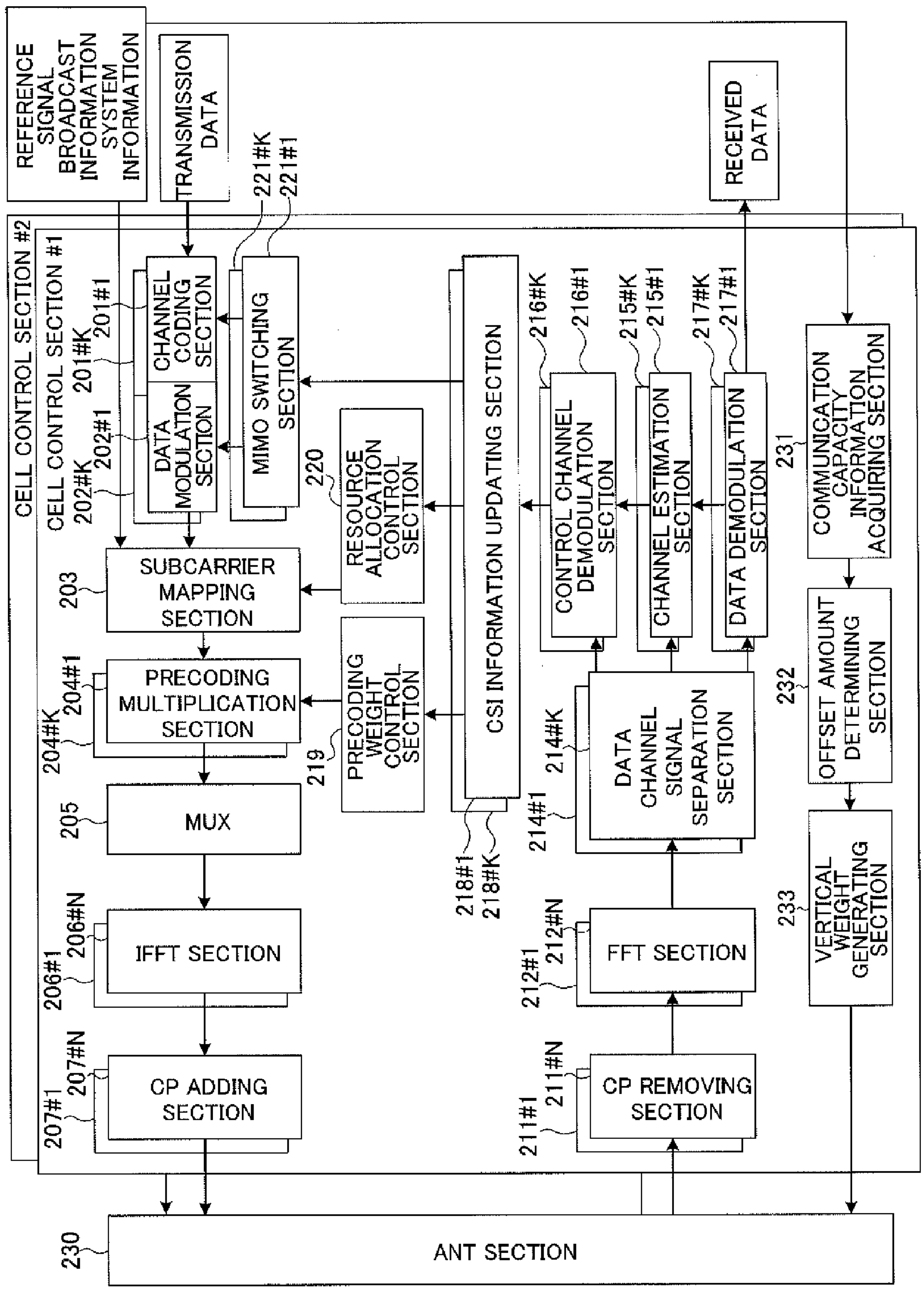

REFERENCE SIGNAL
BROADCAST INFORMATION
SYSTEM INFORMATION
TRANSMISSION DATA
RECEIVED DATA
CELL CONTROL SECTION #2
CELL CONTROL SECTION #1
221#K
221#1
201#1
201#K
202#1
202#K
CHANNEL CODING SECTION
DATA MODULATION SECTION
MIMO SWITCHING SECTION
RESOURCE ALLOCATION CONTROL SECTION
220
CSI INFORMATION UPDATING SECTION
216#K
216#1
215#K
215#1
217#K
217#1
CONTROL CHANNEL DEMODULATION SECTION
CHANNEL ESTIMATION SECTION
DATA DEMODULATION SECTION
231
COMMUNICATION CAPACITY INFORMATION ACQUIRING SECTION
203
SUBCARRIER MAPPING SECTION
204#1
204#K
PRECODING MULTIPLICATION SECTION
PRECODING WEIGHT CONTROL SECTION
219
214#K
214#1
DATA CHANNEL SIGNAL SEPARATION SECTION
232
OFFSET AMOUNT DETERMINING SECTION
205
MUX
218#1
218#K
206#N
206#1
IFFT SECTION
212#N
212#1
FFT SECTION
233
VERTICAL WEIGHT GENERATING SECTION
207#N
207#1
CP ADDING SECTION
211#N
211#1
CP REMOVING SECTION
230
ANT SECTION

FIG.18

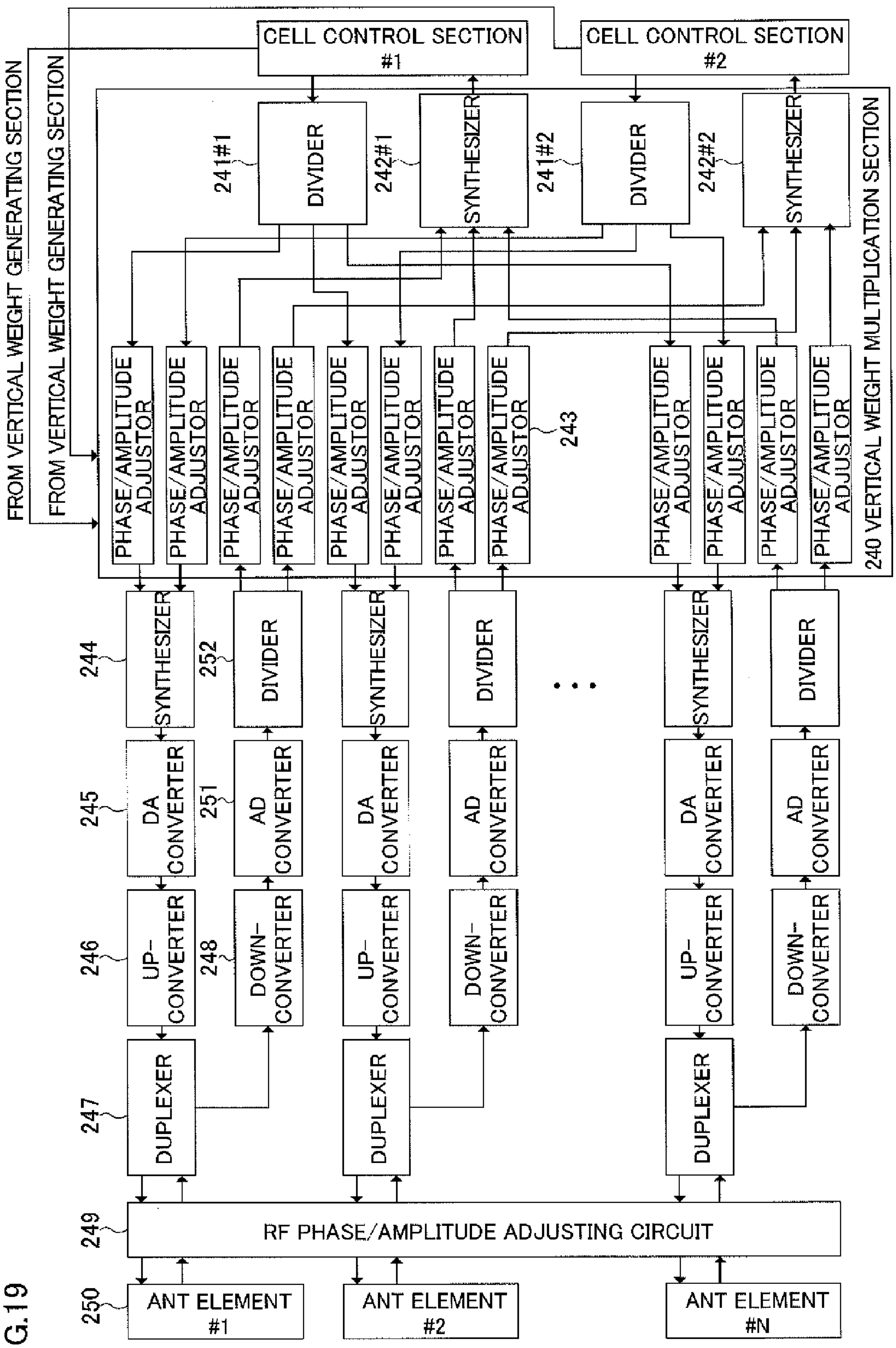

CELL CONTROL SECTION #1
CELL CONTROL SECTION #2
FROM VERTICAL WEIGHT GENERATING SECTION
FROM VERTICAL WEIGHT GENERATING SECTION
241#1
DIVIDER
242#1
SYNTHESIZER
241#2
DIVIDER
242#2
SYNTHESIZER
240 VERTICAL WEIGHT MULTIPLICATION SECTION
PHASE/AMPLITUDE ADJUSTOR
243
244
SYNTHESIZER
252
DIVIDER
245
DA CONVERTER
251
AD CONVERTER
246
UP-CONVERTER
248
DOWN-CONVERTER
247
DUPLEXER
249
RF PHASE/AMPLITUDE ADJUSTING CIRCUIT
250
ANT ELEMENT #1
ANT ELEMENT #2
ANT ELEMENT #N

FIG.19

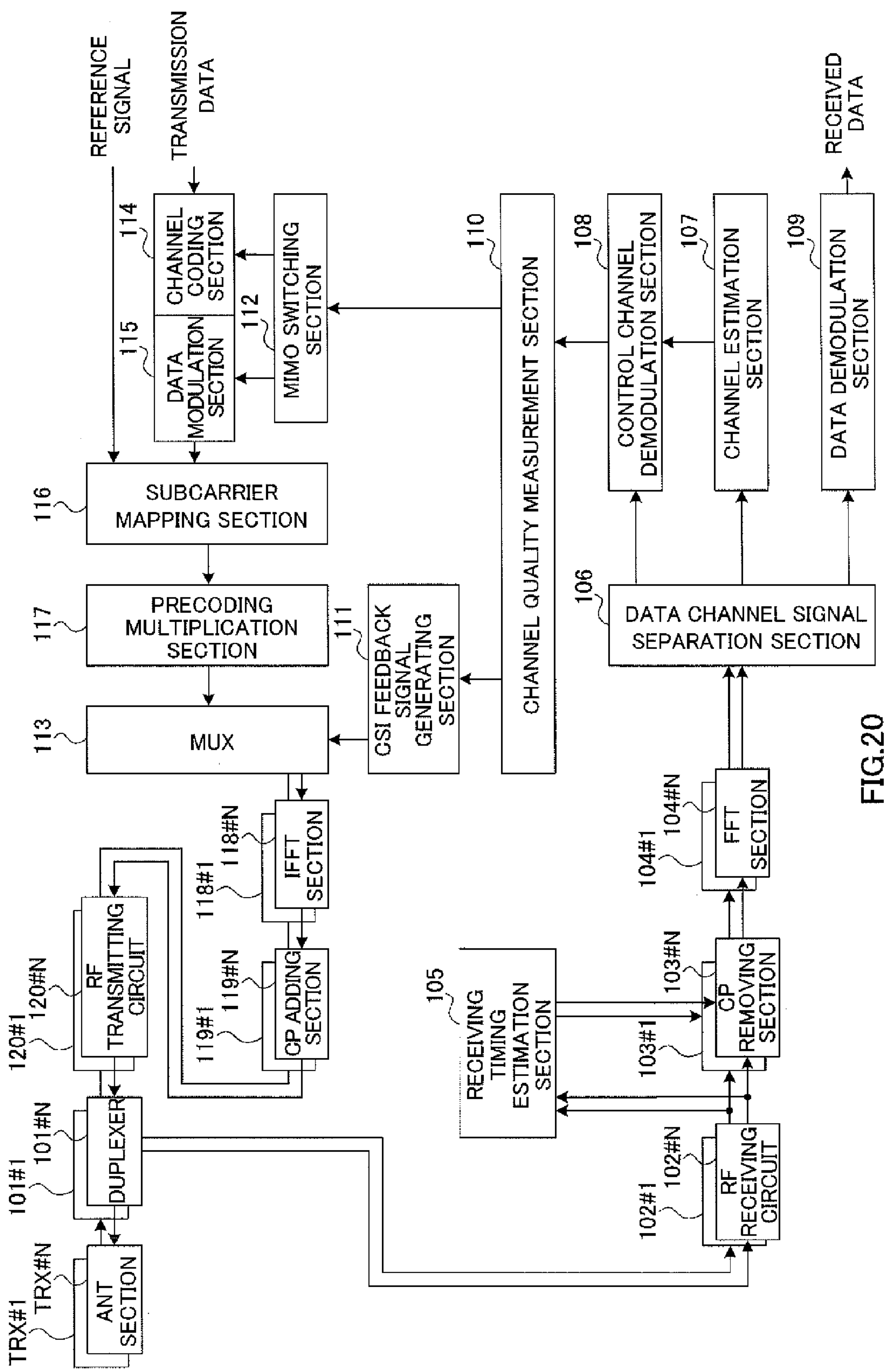
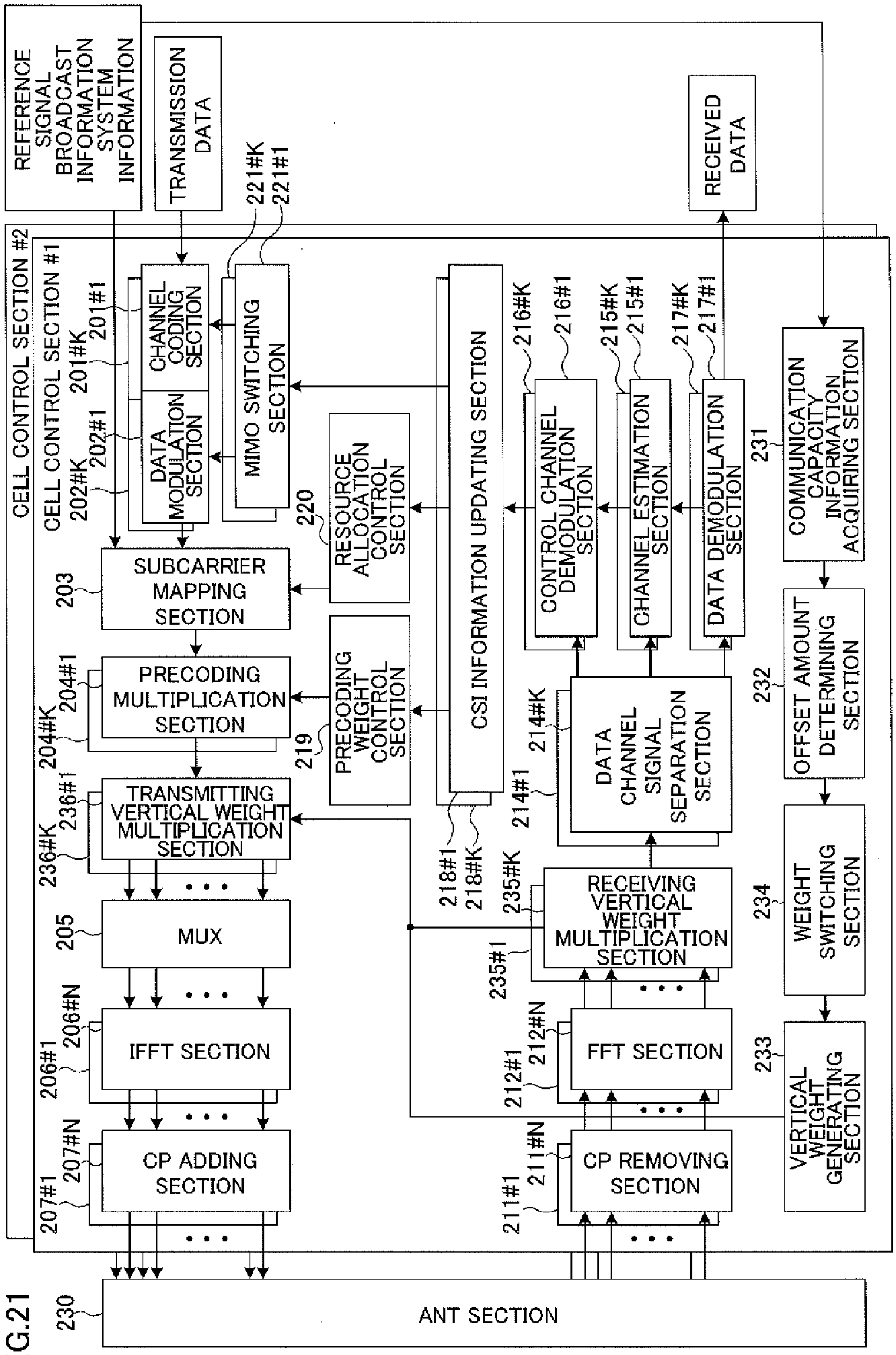

REFERENCE SIGNAL
TRANSMISSION DATA
RECEIVED DATA
114
CHANNEL CODING SECTION
115
DATA MODULATION SECTION
112
MIMO SWITCHING SECTION
110
CHANNEL QUALITY MEASUREMENT SECTION
108
CONTROL CHANNEL DEMODULATION SECTION
107
CHANNEL ESTIMATION SECTION
109
DATA DEMODULATION SECTION
116
SUBCARRIER MAPPING SECTION
117
PRECODING MULTIPLICATION SECTION
111
CSI FEEDBACK SIGNAL GENERATING SECTION
106
DATA CHANNEL SIGNAL SEPARATION SECTION
113
MUX
118#1
118#N
IFFT SECTION
104#1
104#N
FFT SECTION
120#1
120#N
RF TRANSMITTING CIRCUIT
119#1
119#N
CP ADDING SECTION
105
RECEIVING TIMING ESTIMATION SECTION
103#1
103#N
CP REMOVING SECTION
101#1
101#N
DUPLEXER
102#1
102#N
RF RECEIVING CIRCUIT
TRX#1
TRX#N
ANT SECTION

FIG.20



REFERENCE SIGNAL BROADCAST INFORMATION SYSTEM INFORMATION
TRANSMISSION DATA
RECEIVED DATA
CELL CONTROL SECTION #2
CELL CONTROL SECTION #1
201#1
201#K
CHANNEL CODING SECTION
202#1
202#K
DATA MODULATION SECTION
221#K
221#1
MIMO SWITCHING SECTION
220
RESOURCE ALLOCATION CONTROL SECTION
CSI INFORMATION UPDATING SECTION
218#1
218#K
216#K
216#1
CONTROL CHANNEL DEMODULATION SECTION
215#K
215#1
CHANNEL ESTIMATION SECTION
217#K
217#1
DATA DEMODULATION SECTION
231
COMMUNICATION CAPACITY INFORMATION ACQUIRING SECTION
203
SUBCARRIER MAPPING SECTION
204#1
204#K
PRECODING MULTIPLICATION SECTION
219
PRECODING WEIGHT CONTROL SECTION
214#K
214#1
DATA CHANNEL SIGNAL SEPARATION SECTION
232
OFFSET AMOUNT DETERMINING SECTION
236#1
236#K
TRANSMITTING VERTICAL WEIGHT MULTIPLICATION SECTION
235#K
235#1
RECEIVING VERTICAL WEIGHT MULTIPLICATION SECTION
234
WEIGHT SWITCHING SECTION
205
MUX
206#N
206#1
IFFT SECTION
212#N
212#1
FFT SECTION
233
VERTICAL WEIGHT GENERATING SECTION
207#N
207#1
CP ADDING SECTION
211#N
211#1
CP REMOVING SECTION
230
ANT SECTION

FIG.21

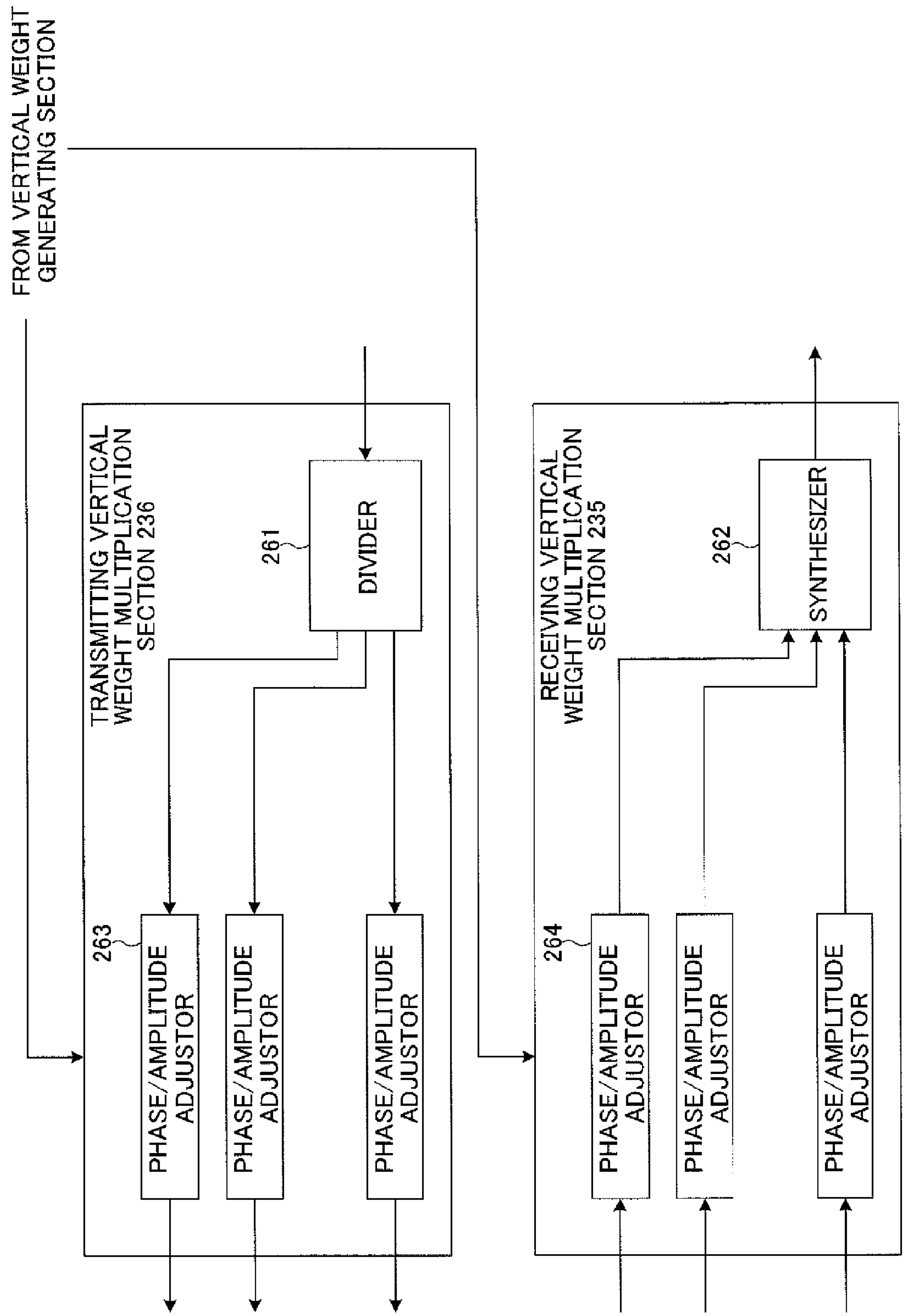

FROM VERTICAL WEIGHT GENERATING SECTION
TRANSMITTING VERTICAL WEIGHT MULTIPLICATION SECTION 236
261
DIVIDER
263
PHASE/AMPLITUDE ADJUSTOR
PHASE/AMPLITUDE ADJUSTOR
PHASE/AMPLITUDE ADJUSTOR
RECEIVING VERTICAL WEIGHT MULTIPLICATION SECTION 235
262
SYNTHESIZER
264
PHASE/AMPLITUDE ADJUSTOR
PHASE/AMPLITUDE ADJUSTOR
PHASE/AMPLITUDE ADJUSTOR

FIG.22

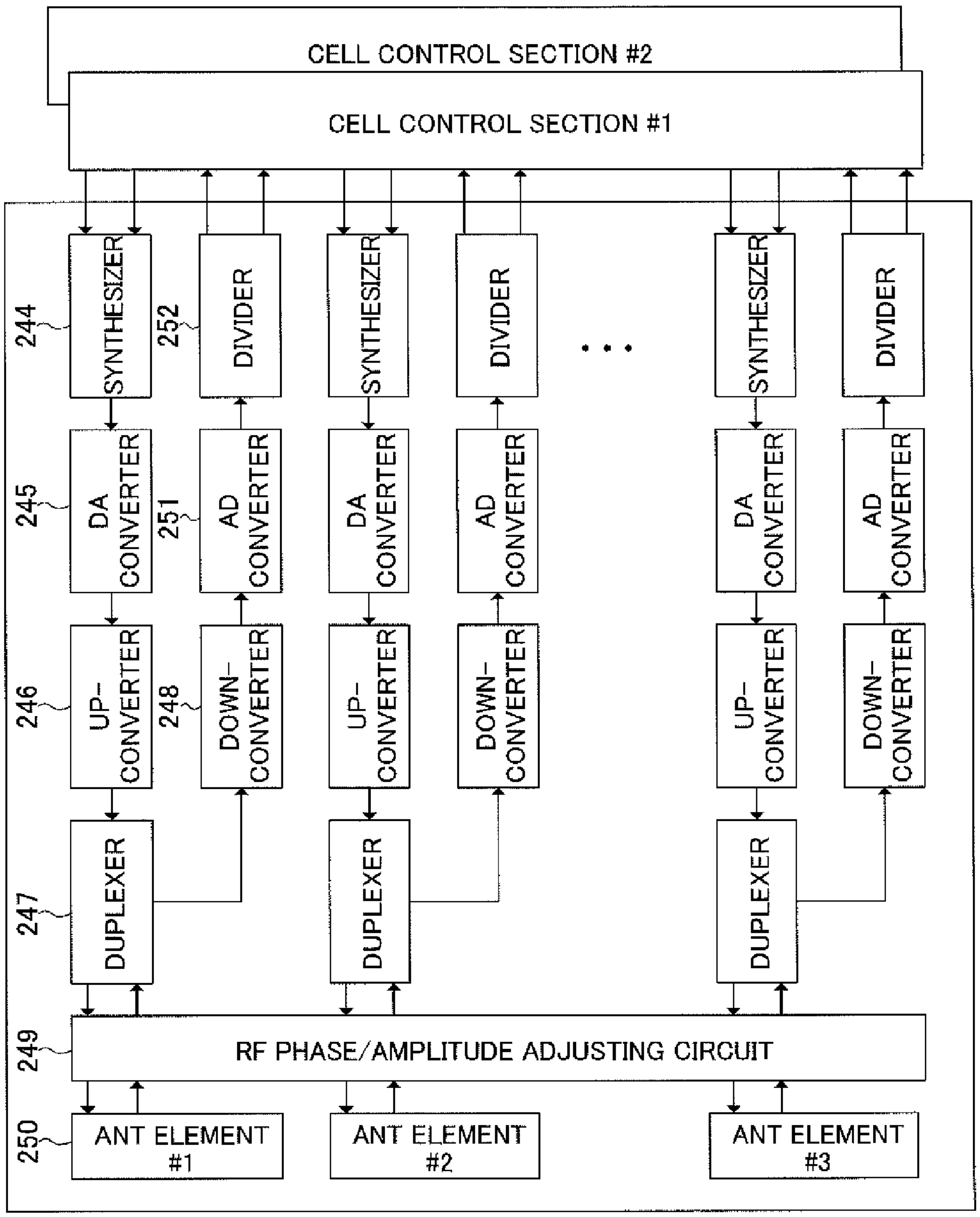

CELL CONTROL SECTION #2
CELL CONTROL SECTION #1
244
SYNTHESIZER
252
DIVIDER
SYNTHESIZER
DIVIDER
SYNTHESIZER
DIVIDER
245
DA CONVERTER
251
AD CONVERTER
DA CONVERTER
AD CONVERTER
DA CONVERTER
AD CONVERTER
246
UP-CONVERTER
248
DOWN-CONVERTER
UP-CONVERTER
DOWN-CONVERTER
UP-CONVERTER
DOWN-CONVERTER
247
DUPLEXER
DUPLEXER
DUPLEXER
249
RF PHASE/AMPLITUDE ADJUSTING CIRCUIT
250
ANT ELEMENT #1
ANT ELEMENT #2
ANT ELEMENT #3

FIG.23

RADIO BASE STATION, RADIO COMMUNICATION SYSTEM AND RADIO COMMUNICATION METHOD

TECHNICAL FIELD

The present invention relates to a radio base station, a radio communication system and a radio communication method that are applicable to a next-generation mobile communication system.

BACKGROUND ART

In a UMTS (Universal Mobile Telecommunications System) network, attempts are made to optimize features of the system, which are based on W-CDMA (Wideband Code Division Multiple Access), by adopting HSDPA (High Speed Downlink Packet Access) and HSUPA (High Speed Uplink Packet Access), for the purposes of improving spectral efficiency and improving the data rates. With this UMTS network, long-term evolution (LTE) is under study for the purposes of further increasing high-speed data rates, providing low delay, and so on.

In a third-generation system, a transmission rate of maximum approximately 2 Mbps can be achieved on the downlink by using a fixed band of approximately 5 MHz. Meanwhile, in a system of the LTE scheme, it is possible to achieve a transmission rate of about maximum 300 Mbps on the downlink and about 75 Mbps on the uplink, by using a variable band which ranges from 1.4 MHz to 20 MHz. Furthermore, with the UMTS network, successor systems of LTE are also under study for the purpose of achieving further broadbandization and higher speed (for example, "LTE-Advanced" (LTE-A)). For example, in LTE-A, there is a plan to expand the maximum system band for LTE specifications, which is 20 MHz, to approximately 100 MHz.

Also, in a system of the LTE scheme, a MIMO (Multi Input Multi Output) system is proposed (see, for example, non-patent literature 1), as a radio communication technique to transmit and receive data by a plurality of antennas and improve the data rate (spectral efficiency). In the MIMO system, a plurality of transmitting/receiving antennas are provided in the transmitter/receiver, so that different transmission information sequences are transmitted from different transmitting antennas at the same time. Meanwhile, on the receiver side, taking advantage of the fact that fading variation is produced differently between the transmitting/receiving antennas, it is possible to increase the data rate (spectral efficiency) by separating and detecting the information sequences that have been transmitted at the same time.

Now, in recent years, vertical sectorization (VSEC) has been gaining popularity as a technique to secure communication capacity in a radio communication system. For example, a proposal has been made to improve the throughput of each cell by outputting a plurality of beams having varying beam angles (tilt angles) with respect to horizontal directions from an antenna apparatus, and setting the tilt angles of the beams in accordance with the conditions of radio base stations (see, for example, non-patent literature 2).

CITATION LIST

Non-Patent Literature

Non-Patent Literature 1: 3GPP TR 25.913 "Requirements for Evolved UTRA and Evolved UTRAN"

Non-patent literature 2: O. N. C. Yilmaz et al., "System Level Analysis of Vertical Sectorization for 3GPP LTE," Proc. of ISWCS, 2009.

SUMMARY OF INVENTION

Technical Problem

However, in VSEC, there is a threat that, due to the conditions in which radio base stations are provided and so on, differences are produced in the number of user terminals that are present, between a plurality of cells that are vertically sectorized, and as a result of this differences in each cell's communication capacity are produced. When the number of user terminals connected to each cell varies significantly, resources that can be allocated to one user terminal also differ significantly, which makes effective use of radio resources difficult.

The present invention has been made in view of the above, and it is therefore an object of the present invention to allow effective use of radio resources in VSEC to output a plurality of beams of varying tilt angles for sectorization in vertical directions.

Solution to Problem

The radio communication method of the present invention is a radio communication method for a radio base station that outputs a plurality of beams of varying tilt angles and forms a plurality of cells that are sectorized vertically, and a user terminal that establishes wireless connection with the radio base station, and this radio communication method provides the steps in which the radio base station acquires information about communication capacity of each of the plurality of cells, and controls a vertical plane beam width and/or transmission power of each cell and sets a coverage area of each cell such that differences in communication capacity between the plurality of cells are reduced.

Advantageous Effects of Invention

According to the present invention, it is possible to make effective use of radio resources in VSEC to output a plurality of beams of varying tilt angles for sectorization in vertical directions.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** provides diagrams to show two cells (an inner cell and an outer cell) that are vertically sectorized;

FIG. **2** provides diagrams to show a plurality of cells (three or more cells) that are vertically sectorized;

FIG. **3** is a diagram to show two cells (an inner cell and an outer cell) that are vertically sectorized, and resource allocation to user terminals that are present in the inner cell and the outer cell;

FIG. **4** is a diagram to show resource allocation to user terminals that are present in each of a plurality of cells that are vertically sectorized;

FIG. **5** is a diagram to show an example of a case where the coverage areas of an inner cell and an outer cell are controlled by changing the vertical plane beam width;

FIG. **6** is a diagram to show an example of a case where the coverage areas of an inner cell and an outer cell are controlled by changing transmission power;

FIG. **7** is a diagram to show an example of a case where the coverage areas of a plurality of cells (three or more cells) are controlled by changing the vertical plane beam width and/or transmission power;

FIG. **8** is a diagram to show an example of power resource allocation control for each cell based on the number of user terminals that are present in an inner cell and an outer cell;

FIG. **9** is a diagram to show an example of power resource allocation control for each cell based on the number of user terminals that are present in each of a plurality of cells;

FIG. **10** provides diagrams to show examples of resource allocation control for each cell based on the number of user terminals that are present in an inner cell and an outer cell;

FIG. **11** is a diagram to show an example of a case where resources in each cell are controlled by controlling the increase/decrease of power in each cell and also by synchronizing the antenna gain, beam width or tilt angle between cells, in time, based on the number of user terminals that are present in an inner cell and an outer cell;

FIG. **12** is a diagram to show examples of resource allocation control for each cell based on the number of user terminals that are present in each of a plurality of cells;

FIG. **13** is a diagram to show an example of a case where resources in each cell are controlled by controlling the increase/decrease of power in each cell and also by synchronizing the antenna gain, beam width or tilt angle between cells, in time, based on the number of user terminals that are present in each of a plurality of cells;

FIG. **14** is a diagram to show an example of a case where resources in each cell are controlled by executing ON/OFF control of each cell and also by synchronizing the antenna gain, beam width or tilt angle between cells, in time, based on the number of user terminals that are present in an inner cell and an outer cell, and the coverage area of one cell is expanded;

FIG. **15** is a diagram to show an example of a case where resources in each cell are controlled by executing ON/OFF control of each cell and also by synchronizing the antenna gain, beam width or tilt angle between cells, in time, based on the number of user terminals that are present in each of a plurality of cells, and the coverage area of a specific cell is expanded;

FIG. **16** provides conceptual diagrams of array antennas constituting an antenna apparatus;

FIG. **17** is a diagram to show a network configuration of a radio communication system according to an embodiment;

FIG. **18** is a block diagram to show a configuration of a radio base station according to an embodiment;

FIG. **19** is a block diagram to show a configuration of an antenna section according to an embodiment;

FIG. **20** is a block diagram to show a configuration of a mobile station according to an embodiment;

FIG. **21** is a block diagram to show another configuration of a radio base station according to an embodiment;

FIG. **22** is a block diagram to show a transmitting/receiving vertical weight multiplication section in a radio base station; and

FIG. **23** is a block diagram to show another configuration of an antenna section according to an embodiment.

DESCRIPTION OF EMBODIMENTS

First, a case will be described where a radio base station outputs a plurality of beams with varying tilt angles via an antenna and forms a plurality of cells that are vertically sectorized. In the following description, a case of forming two cells and a case of forming three or more cells will be

described. Where two cells are vertically sectorized, one will be referred to as the "inner cell," and the other one will be referred to as the "outer cell." Note that, with the present embodiment, the "tilt angle" refers to the angle of beams with respect to horizontal directions (for example, the ground). Also, with the present embodiment, dividing space into a plurality of sectors by means of a plurality of beams having varying tilt angles will be referred to as vertical sectorization, for ease of explanation. Note that the present inventors have proposed the method of controlling VSEC earlier in Japanese Patent Application No. 2011-177604.

FIG. **1** and FIG. **2** show that a plurality of beams with varying tilt angles are output from one antenna and a plurality of cells are vertically sectorized. As shown in FIG. **1**A, when two beams with mutually varying tilt angles are output, a cell (inner cell) that is relatively close to a radio base station and a cell (outer cell) that is relatively far are formed. The tilt angle of the beam forming the inner cell (inner tilt angle) is greater than the tilt angle of the beam forming the outer cell (outer tilt angle). Also, as shown in FIG. **2**A, by increasing the number of beams having varying tilt angles, it is possible to increase the number of vertically sectorized cells.

Also, by outputting a plurality of beams having varying tilt angles with respect to varying horizontal directions, it is possible to form a plurality of cells that are vertically sectorized with respect to varying horizontal directions. For example, in a two-cell configuration, a plurality of inner cells (here, cell #**4** to cell #**6**) and outer cells (here, cell #**1** to cell #**3**) are formed (see FIG. **1**B). Also, in a configuration with three or more cells, a plurality of cells that are vertically sectorized are formed (here, the vertical sectorization group of cell #**1**, cell #K+1, . . . , and cell #K (N−1)+1, and the vertical sectorization group of cell #**2**, cell #K+2, . . . and cell #K (N−1)+2) (see FIG. **2**B). Note that, in FIG. **2**, N is the number of vertical sectors, and K is the number of horizontal sectors.

A plurality of beams output from a radio base station may be output from one antenna or may be output from a plurality of antennas separately. Note that, although a case will be shown in the following description where a plurality of beams are output from one antenna, it is equally possible, with the present embodiment, to output beams of varying tilt angles from a plurality of (two or more) antennas.

As shown in FIG. **1** and FIG. **2**, it is possible to improve the throughput of cells by forming multiple cells that are vertically sectorized, and by adequately setting the tilt angles of the beams forming each cell in accordance with the state of the radio base stations. However, even when the tilt angles of a plurality of cells are controlled in VSEC, cases might occur where, due to the conditions in which the radio base stations are provided and so on, the number of user terminals (or the number of active users) that are present in each cell varies significantly, and differences in communication capacity increase between cells. As a result, there is a threat that resources cannot be allocated evenly to the user terminals that are present in each cell, and it becomes not possible to make effective use of radio resources (the speed of communication decreases).

For example, as shown in FIG. **3**, when the number of user terminals connected to the inner cell and the number of user terminals connected to the outer cell vary in proportion (that is, when the proportion of connecting user terminals varies), resources that can be allocated to one user terminal also vary between the inner cell and the outer cell. In FIG. **3**, the number of user terminals that are present in the coverage area of the inner cell is two (the connecting proportion is

2/10), and the number of user terminals that are present in the coverage area of the outer cell is eight (the connecting proportion is 8/10).

When the amount of resources that can be allocated to user terminals is the same between the inner cell and the outer cell, the number of resources that can be allocated to one user terminal in the inner cell is greater than the number of resources that can be allocated to one user terminal in the outer cell. In this case, it may occur that resources to allocate to the user terminals of the inner cell are superabundant, and resources to allocate to the user terminals of the outer cell run short. As a result, it becomes difficult to make effective use of radio resources in the inner cell and the outer cell.

Similarly, as shown in FIG. **4**, in cases where three or more cells are formed, when the proportion of the number of user terminals connected to each cell (the proportion of connecting user terminals) varies, differences are produced in resources that are available for allocation to one user terminal, and therefore differences in resources are produced between cells, and it becomes difficult to make effective use of radio resources. In FIG. **4**, the number of user terminals that are present in the coverage area of the innermost cell (cell #K(N−1)+1) is one (the connecting proportion is 1/M), the number of user terminals that are present in the coverage area of the second outermost cell (cell #K+1) is four (the connecting proportion is 4/M), and the number of user terminals that are present in the coverage area of the outermost cell (cell #**1**) is two (the connecting proportion is 2/M). In this case, there is a threat that resources to allocate to the innermost cell (#K(N−1)+1) become superabundant, and resources to allocate to the user terminals in cell (cell #K+1) run short. Note that, in FIG. **4**, N is the number of vertical sectors, K is the number of horizontal sectors, and M is the total number of user terminals per horizontal sector.

So, the present inventors have come up with the idea that it is possible to make effective use of radio resources in VSEC by changing the antenna gain, beam width and so on, on a per cell basis, and controlling coverage areas based on the communication capacity of each of a plurality of cells (for example, the number of user terminals that are present in each cell, the number of active users, or statistics of these), or by controlling the resources for each cell by controlling the increase/decrease of power in each cell or executing ON/OFF control, by synchronizing the antenna gain, beam width or tilt angle on a per cell basis.

Now, the method of controlling the coverage area of each cell and the method of controlling resource allocation when outputting a plurality of beams of varying tilt angles and vertically sectorizing a plurality of cells will be described below in detail. Note that, although, in the following description, a case will be shown in detail as an example where, in a two-cell configuration, the number of user terminals that are present in the coverage area of the inner cell is lower than the number of user terminals that are present in the coverage area of the outer cell, the present embodiment is by no means limited to this.

Also, although, in the following description, a case where the number of user terminals that are present in each cell is used as an evaluation indicator will described as an example of a case where each cell's coverage area control and resource allocation control are carried out based on each cell's communication capacity, the present embodiment is by no means limited to this. It is equally possible to design the coverage area control and resource allocation control for each cell by using, as evaluation indicators, the number of active users in each cell, the amount of resources consumed in each cell, the throughput of each cell, statistics given by statistically calculating and processing these, values given by mathematically calculating these based on design values, and values predicted from past statistics and system simulations, and so on.

(Coverage Area Control)

When the coverage areas of cells are controlled separately based on the number of user terminals that are present in each cell, a radio base station first acquires information about the number of user terminals present in each cell. This information is converted into data of the proportion of connecting user terminals per cell (the number of user terminals connected to each cell/the total number of user terminals connected to all cells). Information about the number of user terminals that are present in each cell can be acquired, for example, from system information that is output from the network side.

Also, besides actually counting the number of user terminals that are connected to each cell and perform radio communication, the number of user terminals connected to each cell can be determined in various other methods. For example, the number of user terminals present in each cell may be calculated based on the assumption that the user terminals are distributed uniformly over the area where each cell is formed. In this case, the number of user terminals that are connected to each cell is calculated depending on the area of each cell.

Also, it is equally possible to apply, as information about the number of user terminals, statistics given by calculating and processing the number of user terminals statistically, values given by calculating the number of user terminals taking into account the conditions of design of the radio base stations (for example, the place where each cell is formed, and so on), or values given by predicting the number of user terminals from past statistics, system simulations and so on. The conditions in which radio base stations are provided match the surrounding environment such as the positions where the radio base stations are provided (the height, place and so on), the place where each cell is formed, and so on.

Based on the acquired information about the proportion of connecting user terminals in each cell, the radio base station sets each cell's coverage area conditions (for example, the size of the coverage area) such that differences in the proportion of user terminals connected to each cell are reduced. For example, when the proportion of connecting user terminals in a given cell is lower than the average value of the proportions of connecting user terminals of all cells (that is, the reciprocal of the number of all cells, which is 1/2 in a two-cell configuration), conditions to increase the coverage size are set, and when the proportion of connecting user terminals in a given cell is higher than the average value of the proportions of connecting user terminals of all cells (that is, the reciprocal of the number of all cells, which is 1/2 in a two-cell configuration), conditions to reduce the coverage size are set.

Then, based on the coverage area conditions, the conditions of beams to form each cell (for example, the tilt angle of each cell, the transmission power of each cell, the antenna gain of each cell, the vertical plane beam width of each cell (HPBW: half-power bandwidth)) are determined, and the size and position of each cell's coverage area are changed in accordance with the proportion of connecting user terminals. Now, a case of controlling the vertical plane beam width of each cell and the transmission power of each cell will be described below with reference to the accompanying drawings. Note that, in the following description, a cell where the proportion of connecting user terminals is lower than the average value of the proportions of connecting user terminals of all cells (that is, the reciprocal of the number of all cells, which is 1/2 in a two-cell configuration) will be defined as a "cell where the proportion of connecting user terminals is low," and a cell where the proportion of connecting user terminals is higher than the average value of the proportions of connecting user terminals of all cells (that is, the reciprocal of the number of all cells, which is 1/2 in a two-cell configuration) will be defined as a "cell where the proportion of connecting user terminals is high."

<Vertical Plane Beam Width Control>

When the coverage area of each cell is controlled by changing the vertical plane beam width, the radio base station narrows the vertical plane beam width in cells where the proportion of connecting user terminals is high, in accordance with the proportion of connecting user terminals, and widens the vertical plane beam width of cells where the proportion of connecting user terminals is low, in accordance with the proportion of connecting user terminals (see FIG. **5**). To be more specific, the radio base station determines the offset values of the vertical plane beam widths of the beams forming each cell, based on the proportion of connecting user terminals in each cell, on a per cell basis. Then, based on the determined offset values, weights (phase and amplitude) to apply to the antenna section are generated, and the vertical plane beam widths of the beams to output are changed by multiplying the transmission signals by the weights.

In this way, by reducing the coverage area of cells where the proportion of connecting user terminals is high in accordance with the proportion of connecting user terminals, and by broadening the coverage area of cells where the proportion of connecting user terminals is low in accordance with the proportion of connecting user terminals, differences in the proportion of connecting user terminals in each cell are reduced. In other words, it is possible to make the number of user terminals present in each cell substantially equal.

FIG. **5** shows, for example, a case of control in a two-cell configuration, and a case where a user terminal connected to an outer cell is connected to an inner cell by widening the vertical plane beam width of the inner cell in accordance with the proportion of connecting user terminals and by narrowing the vertical plane beam width of the outer cell in accordance with the proportion of connecting user terminals. In this way, by controlling the vertical plane beam width of each cell based on the proportion of connecting user terminals in each cell, the proportion of connecting user terminals becomes even between cells, and therefore it is possible to allocate resources to the user terminals in each cell evenly. As a result, it is possible to use radio resources without unevenness between user terminals.

Also, in a predetermined period of time after changing the coverage area of each cell, the radio base station can repeat the process of re-acquiring information about the number of user terminals present in each cell and re-setting the coverage areas by changing the vertical plane beam width of each cell in the same way as described above. By repeating the process of setting the coverage areas of cells, it is possible to make the differences in the number of user terminals between cells even smaller, and allow optimization so that radio resources are used without unevenness between user terminals. Alternatively, it is also possible to count active users on a real-time basis, and, in accordance with this, allow optimization so that radio resources are used without unevenness between user terminals.

Note that, as for the vertical plane beam width offset values, it is possible to prepare various combinations of amounts of offset in a database and determine predetermined offset values in accordance with the proportion of connecting user terminal in each cell. The database in which amounts of offset are defined can be prepared based on information that is acquired earlier in other radio base stations, values calculated based on simulation, and so on.

Also, with the present embodiment, the radio base station may control the coverage areas of cells not only by changing the vertical plane beam width but also by changing the horizontal plane beam width. In this case, it is possible to provide vertical arrays and horizontal arrays as antenna elements, and multiply transmission signals by vertical weights and horizontal weights.

<Power Offset Control>

When the coverage area of each cell is controlled by changing transmission power (power), the radio base station lowers the transmission power of cells where the proportion of connecting user terminals is high in accordance with the proportion of connecting user terminals, and increases the transmission power of cells where the proportion of connecting user terminals is low in accordance with the proportion of connecting user terminals (see FIG. **6**). To be more specific, the radio base station determines the transmission power offset value for each cell based on the proportion of connecting user terminals in each cell. Then, the input signals to each beam are changed on the basis of the determined offset value.

FIG. **6** shows, as an example, a case of control in a two-cell configuration, where a user terminal connected to an outer cell is connected to an inner cell by increasing the transmission power of the inner cell in accordance with the proportion of connecting user terminals, and by lowering the transmission power of the outer cell in accordance with the proportion of connecting user terminals. In this way, by controlling the transmission power of each cell based on the proportion of connecting user terminals in each cell, the proportion of connecting user terminals becomes even between cells, so that it is possible to allocate resources to user terminals in each cell evenly. As a result, it is possible to use radio resources without unevenness between user terminals.

Also, in a predetermined period of time after changing the coverage area of each cell, the radio base station can re-acquire information about the number of user terminals present in each cell, and change the transmission power of each cell in the same way as described above. By repeating the process of re-setting the coverage areas, it is possible to reduce the differences in the number of user terminals between cells and allow optimization so that radio resources are used without unevenness between user terminals. Alternatively, it is equally possible to count active users on a real-time basis, and, in accordance with this, allow optimization so that radio resources are used without unevenness between user terminals.

Note that, as for the transmission power offset values, it is possible to prepare various combinations of amounts of offset in a database, and determine predetermined offset values in accordance with the proportion of connecting user terminals in each cell. The database in which amounts of offset are defined can be prepared based on information that is acquired earlier in other radio base stations, values calculated based on simulation, and so on.

As has been described above with reference to FIG. **5** and FIG. **6**, by controlling the vertical plane beam width and/or transmission power of each cell based on the proportion of connecting user terminals in each cell, it is possible to reduce the differences in the proportion of connecting user terminals in each cell and allow more effective use of radio resources.

Note that, even when three or more cells are vertically sectorized, similar to the case of two cells, it is possible to control the vertical plane beam width and/or transmission power of each cell based on the proportion of connecting user terminals in each cell. FIG. **7** shows an example of control where the number of vertical sectors is N and the number of horizontal sectors is K (for example, the case of FIG. **2**B). In FIG. **7**, the vertical plane beam width and/or transmission power are controlled so that the coverage areas of cells where the proportion of connecting user terminals is low (#K(N−1)+1 and #**1**) become bigger, and the vertical plane beam width and/or transmission power are controlled so that the coverage area of a cell where the proportion of connecting user terminals is high (cell #K+1) becomes smaller. By this means, it is possible to reduce the differences in the proportion of connecting user terminals in each cell, and allow more effective use of radio resources.

Next, the method of controlling the resource allocation to each cell based on the proportion of connecting user terminals in each cell will be described.

(Resource Allocation Control)

When the resource allocation for each cell is controlled based on the number of user terminals that are present in each cell, the radio base station first acquires information about the number of user terminals that are present in each cell. This information is converted into data of the proportion of user terminals connected to each cell (the number of user terminals connected to each cell/the total number of user terminals in all cells). The information about the proportion of connecting user terminals is acquired in various methods such as ones described above.

The radio base station changes the amount of (power) resources to allocate to each cell in accordance with the acquired information about the proportion of connecting user terminals. To be more specific, the amount of (power) resources to allocate to cells where the proportion of connecting user terminals is low is set low in accordance with the proportion of connecting user terminals. The amount of (power) resources to allocate to cells where the proportion of connecting user terminals is high is set large in accordance with the proportion of connecting user terminals. The radio base station outputs the beams to form each cell and allocate resources to the user terminals present in each cell based on the conditions of the amount of (power) resources to allocate to each cell.

FIG. **8** shows, as an example, an example of control in a two-cell configuration, and a case where the radio base station reduces the amount of (power) resources to allocate to a cell where the proportion of connecting user terminals is low, and increases the amount of (power) resources to allocate to a cell where the proportion of connecting user terminals is high. By this means, the amount of (power) resources in each cell is determined in accordance with the proportion of connecting user terminals, it is possible to control the amount of (power) resources to allocate per user terminal in each cell is controlled to be equal. By this means, it is possible to allow optimization so that radio resources are used without unevenness between user terminals.

Also, as shown in FIG. **9**, even when three or more cells are vertically sectorized, it is possible to control the amount of (power) resources to allocate to each cell in accordance with the proportion of connecting user terminals. FIG. **9** shows a case where the amount of (power) resources to allocate to each cell is controlled in proportion with the proportion of connecting user terminals (a case where 1×K/M is allocated to cell #K(N−1)+1, 4×K/M is allocated to cell #K+1, and 2×K/M is allocated to cell #**1**).

Although a case has been described above where, when allocating (power) resources, the allocation of power is changed in accordance with the proportion of connecting user terminals, this is by no means limiting. Besides, the frequency band may be divided and resources may be allocated in accordance with the proportion of connecting user terminals, or time may be divided and resources to match the proportion of connecting user terminals may be allocated, or, it is equally possible to combine these and allocate resources to match the proportion of connecting user terminals, so that it is possible to allow optimization in which radio resources are used without unevenness between user terminals.

FIG. **10** shows, an example of control in a two-cell configuration, and shows an example of resource allocation control for a cell where the proportion of connecting user terminals is low and a cell where the proportion of connecting user terminals is high. FIG. **10**A shows a state before the resource allocation control. FIG. **10**B shows a case where allocation is controlled in the frequency domain (frequency allocation control). In this case, resources are allocated to the cell where the proportion of connecting user terminals is low (the inner cell in FIG. **10**), limited to a frequency range narrower than before the resource allocation control is executed, in accordance with the proportion of connecting user terminals. Meanwhile, to the cell where the proportion of connecting user terminals is high (the outer cell in FIG. **10**), resources are allocated by using a wider frequency range than before the resource allocation control, in accordance with the proportion of connecting user terminals.

FIG. **10**C shows a case where allocation is controlled in the time domain. In this case, in accordance with the proportion of connecting user terminals, to the cell where the proportion of connecting user terminals is low (the inner cell in FIG. **10**), the time period to allocate resources is made smaller than before the resource allocation control. On the other hand, in accordance with the proportion of connecting user terminals, to the cell where the proportion of connecting user terminals is high (the outer cell in FIG. **10**), the time period to allocate resources is made larger than before the resource allocation control (time allocation control).

To be more specific, as shown in FIG. **10**C and FIG. **11**, a time period t_1, in which resources are allocated to the cell where the proportion of connecting user terminals is high (the outer cell in FIG. **10** and FIG. **11**), and in which resources are not allocated to the cell where the proportion of connecting user terminals is low (the inner cell in FIG. **10** and FIG. **11**), is provided periodically. Also, in this time period t_1, it is preferable to increase the transmission power relatively in the cell where the proportion of connecting user terminals is high.

For example, as shown in FIG. **11**, when user terminals (UE #**1** and UE #**2**) are present in the inner cell and user terminals (UE #**3** to UE #**10**) are present in the outer cell, in time period t_1, resources are allocated selectively to the cell where the proportion of connecting user terminals is high (the outer cell in FIG. **11**), and also the power is increased. By this means, in time period t_1, interference from the cell where the proportion of connecting user terminals is low against the cell where the proportion of connecting user terminals is high is reduced, and furthermore it is possible to allocate more resources to the cell where the proportion of connecting user terminals is high. Also, in the radio base station, it is preferable to allocate resources to a user terminal located on a cell edge (in FIG. **11**, UE #**3**) in time period t_1 where there is no influence of interference from the inner cell.

Also, when three or more cells are vertically sectorized, it is possible to execute frequency allocation control and time allocation control in accordance with the proportion of connecting user terminals. FIG. **12** shows a case where frequency allocation control and time allocation control are executed in accordance with the proportion of connecting user terminals (a case where 1×K/Ms is allocated to cell #K(N−1)+1, 4×K/M is allocated to cell #K+1, and 2×K/M is allocated to cell #**1**). In the time allocation control shown in FIG. **12**, time period t_1, in which resources are not allocated to cell #K+1 and cell #**1** and in which resources are allocated selectively to cell #K(N−1)+1, is provided.

Also, in time period t_1, in which resources are allocated selectively to the cell where the proportion of connecting user terminals is high, resources are not allocated to the cell where the proportion of connecting user terminals is low. Consequently, in time period t_1, it is also possible to change the tilt angles, vertical plane beam widths and/or antenna gains of the cells such that the coverage area of the cell where the proportion of connecting user terminals is high overlaps the coverage area of the cell where the connecting proportion is low (see FIG. **11**).

In this case, control is designed such that the coverage area of the cell where the proportion of connecting user terminals is high (the outer cell in FIG. **11**) expands in the direction toward the coverage area of another cell formed in time period t_2 apart from time period t_1 (which, in FIG. **11**, is the inner cell where the proportion of connecting user terminals is low). To be more specific, the radio base station apparatus changes the tilt angles, vertical plane beam widths and/or antenna gains of the beam to form the cell where the proportion of connecting user terminals is high (for example, in the case of a two-cell configuration, increases the tilt angle of the outer cell). By this means, it is possible to reduce interference against other cells that neighbor the cell where the beam is changed. Also, it is possible to improve communication quality for user terminals (in FIG. **11**, UE #**3**) that are located on the cell edge of the cell where the connecting proportion is high, and located in positions close to the cell where the proportion of connecting user terminals is low.

Also, as shown in FIG. **13**, when three or more cells are vertically sectorized, it is possible to change the coverage area of a cell where the proportion of connecting user terminals is high to overlap the coverage area of a cell where the connecting proportion is low, in time period t_1. In FIG. **13**, in time period t_1, in which resources are allocated selectively to the cell where the proportion of connecting user terminals is high (cell #K+1), control is designed so that the coverage area of cell #K(N−1)+1 expands in the direction of the coverage area of cell #**1**. At this time, a user terminal located on a cell edge (UE #M−2 in FIG. **13**) is not influenced by cell #**1**, so that it is preferable to allocate resources to this user terminal.

<Range Expansion>

Also, with the present embodiment, it is possible to design control to reduce the differences in the proportion of connecting user terminals in each cell by controlling resource allocation and expanding the coverage areas based on the proportion of connecting user terminals in each cell. FIG. **14** shows a case to provide time period t_3, in which the radio base station selectively allocates resources to a cell where the proportion of connecting user terminals is low (the inner cell in FIG. **14**), and expands the coverage area of a cell where the proportion of connecting user terminals is low in this time period t_3 (range expansion).

The radio base station acquires information about the proportion of connecting user terminals in each cell. Also, the radio base station selects, from among the user terminals that are present in the coverage area of a cell where the proportion of connecting user terminals is high (for example, the outer cell in the two-cell configuration of FIG. **14**) (UEs #**3** to #**10**), predetermined user terminals (in FIG. **14**, UEs #**3** to #**5**) that can connect with a cell where the proportion of connecting user terminals is low (for example, the inner cell in the two-cell configuration of FIG. **14**) with predetermined quality or above.

Also, time period t_3 is periodically provided, in which the radio base station allocates resources to the cell where the proportion of connecting user terminals is low and does not allocate resources to the cell where the proportion of connecting user terminals is high. Furthermore, in this time period t_3, the radio base station connects predetermined user terminals (UEs #**3** to #**5**) to the cell where the proportion of connecting user terminals is low, and allocates resources from the cell where the proportion of connecting user terminals is low. In this way, by controlling the allocation of resources and furthermore expanding the coverage area of a cell where the proportion of connecting user terminals is low, it is possible to reduce the influence of interference from a cell where the proportion of connecting user terminals is high, against predetermined user terminals (UEs #**3** to #**5**) and also allocate resources evenly to the user terminals that are present in each cell.

Also, in time period t_3, in which resources are allocated selectively to a cell where the proportion of connecting user terminals is low, the coverage area of the cell where the proportion of connecting user terminals is low may be changed. For example, in a time period to allocate resources selectively to the cell where the proportion of connecting user terminals is low, it is possible to change the tilt angle and/or the vertical plane beam width of the beam to form the cell where the proportion of connecting user terminals is low such that the coverage area of the cell where the proportion of connecting user terminals is low expands in the direction of the coverage area of a cell where the proportion of connecting user terminals is high, formed in time period t_4 apart from this time period t_3.

In this case, in time period t_3 in which resources are selectively allocated to the cell where the proportion of connecting user terminals is low, it is possible to reduce interference against other cells that neighbor the cell where the proportion of connecting user terminals is low, and also improve communication quality for predetermined user terminals (UEs #**3** to #**5**). Also, it becomes possible to allocate resources to the user terminals in each cell more evenly, so that effective use of radio resources is made possible.

Also, as shown in FIG. **15**, when three or more cells are vertically sectorized, too, it is possible to provide above time period t_3 periodically upon expanding the coverage area (range expansion) of a cell where the proportion of connecting user terminals is low. FIG. **15** shows a case where time period t_3, in which resources are selectively allocated to cells where the proportion of connecting user terminals is low (cell #K(N−1)+1 and cell #**1**), is provided, and the coverage area is expanded (range expansion) in this time period t_3. To be more specific, in time domain t_3, the radio base station makes a predetermined user terminal (UE #**2**) connect with a cell where the proportion of connecting user terminals is low (cell #K(N−1)+1) and makes a user terminal (UE #M−2) connect with cell #**1**, and allocate resources. Also, in time period t_3, it is possible to design control to expand the coverage areas of cells where the proportion of connecting user terminals is low (cell #K(N−1)+1 and cell #**1** in FIG. **15**) in the direction of the coverage area of a cell where the proportion of connecting user terminals is high (cell #K+1 in FIG. **15**) formed in time period t_4 apart from time period t_3.

(Antenna)

The radio communication system according to the present embodiment has a radio base station that can form a plurality of beams that are vertically sectorized, and a user terminal that establishes wireless connection in cells formed by this radio base station, as described above. The radio base station has an antenna that outputs a plurality of beams to sectorize a plurality of cells vertically. As an example of an antenna of this kind, there is an array antenna that is formed with a plurality of antenna elements.

FIG. **16**A is a conceptual diagram of an array antenna. As shown in FIG. **16**A, an array antenna **10** is formed with a plurality of antenna elements **11** that are aligned in a line in one direction. In FIG. **16**A, sixteen antenna elements **11** are shown as an example. With the present embodiment, the array antenna **10** is formed with a polarized antenna that is a combination of a vertically polarized antenna **10***a* and a horizontally polarized antenna **10***b*. However, the antennas that are applicable to the radio base station according to the present embodiment are by no means limited to this antenna configuration. Also, not only vertically polarized and horizontally polarized antennas, but also plus/minus 45-degree polarized antenna elements or an array antenna formed with antenna elements tilting these may be used as well.

FIG. **16**B is a conceptual diagram showing the vertically polarized antenna **10***a* alone, and FIG. **16**C is a conceptual diagram showing the horizontally polarized antenna **10***b* alone. When a polarized antenna is adopted, the individual antenna elements **11** are each formed with a set of vertically polarized elements **11**V and horizontally polarized elements **11**H.

Also, the radio base station is able to provide a plurality of communication types by using the above array antenna formed with a plurality of antenna elements. Now, a first communication type to a third communication type will be described as examples of a plurality of communication types which are applicable to the radio base station.

The first communication type is a type to form one antenna branch with the whole antenna, by forming one group A with all of the antenna elements **11** constituting the array antenna **10**. The second communication type is a type to form two antenna branches with the whole antenna, by forming two groups B**1** and B**2**, which divide the array antenna **10** vertically into two. The third communication type is a type to form four antenna branches, by forming four groups C**1**, C**2**, C**3** and C**4**, which divide the array antenna **10** vertically into four.

Among the first communication type to the third communication type, the length of antennas to constitute one branch is the longest (that is, the number of antenna elements is the largest) with the first communication type. The length of antennas per branch becomes shorter as the number of antenna branches increases (the number of antenna elements decreases). Generally speaking, when beams are formed using an array antenna, it is possible to improve antenna gain and make the beam width smaller, as the number of antenna elements per branch increases. Consequently, according to the first communication type, the whole antenna is formed with one antenna branch, so that the antenna gain is maximized, and therefore it is possible to form sharp beams that are directed toward cell edges.

With the second communication type, the number of antenna elements per branch is half, so that, compared to the first communication type, the antenna gain decreases and furthermore the beam width becomes greater. With the third communication type, the number of antenna elements per branch decreases to 1/2 again from the second communication type, so that, compared to the second communication type, the antenna gain decreases and furthermore the beam width becomes greater.

Note that the present embodiment is not limited to the above first communication type to the third communication type, it is possible to adequately set an arbitrary number of communication types in accordance with the number of divisions of the antenna elements **11** forming the array antenna **10** in vertical directions. Also, the maximum number of branches can be selected as adequate, depending on the antenna elements **11**. Also, the radio communication system according to the present embodiment is able to switch the branch configuration of the array antenna **10** depending on weight.

(Radio Communication System)

Now, the radio communication system according to the above-described embodiment will be described below in detail with reference to the accompanying drawings.

A radio communication system **1** having a user terminal (hereinafter referred to as "mobile station **100**") and a radio base station (eNodeB) **200** according to the present embodiment will be described with reference to FIG. **17**. FIG. **17** is a diagram to explain the configuration of the radio communication system **1** having the mobile station **100** and radio base station **200** according to an embodiment of the present invention. Note that the radio communication system **1** shown in FIG. **17** is a system to accommodate, for example, the LTE system or SUPER 3G. Also, this radio communication system **1** may be referred to as "IMT-Advanced" or may be referred to as "4G."

As shown in FIG. **17**, the radio communication system **1** is configured to include a radio base station **200** and a plurality of mobile stations **100** (100_1, 100_2, 100_3, . . . , 100_n, where n is an integer to satisfy n>0) that communicate with this radio base station **200**. The radio base station **200** is connected with a higher station apparatus **300**, and this higher station apparatus **300** is connected with a core network **400**. The mobile stations **100** communicate with the radio base station **200** in a cell **500**. Note that the higher station apparatus **300** may be, for example, an access gateway apparatus, a radio network controller (RNC), a mobility management entity (MME) and so on, but is by no means limited to these.

The mobile stations (100_1, 100_2, 100_3, . . . , 100_n) have the same configuration, functions and state, and therefore will be described simply as "mobile station **100**," unless specified otherwise. Also, although the mobile station **100** will be described to perform radio communication with the radio base station **200** for ease of explanation, more generally, user equipment (UE) to include both mobile terminal apparatuses and fixed terminal apparatuses may be used as well.

In the radio communication system **1**, as radio access schemes, OFDMA (Orthogonal Frequency Division Multiple Access) is applied to the downlink, and SC-FDMA (Single-Carrier Frequency Division Multiple Access) is applied to the uplink. OFDMA is a multi-carrier transmission scheme to perform communication by dividing a frequency band into a plurality of narrow frequency bands (subcarriers) and mapping data to each subcarrier. SC-FDMA is a single carrier transmission scheme to reduce interference between terminals by dividing, per terminal, the system band into bands formed with one or continuous resource blocks, and allowing a plurality of terminals to use mutually different bands.

Here, communication channels in LTE/LTE-A systems will be described. On the downlink, a PDSCH, which is used by each mobile station **100** on a shared basis, and downlink L**1**/L**2** control channels (PDCCH, PCFICH, PHICH), are used. By means of this PDSCH, user data—that is, normal data signals—is transmitted. Transmission data is included in this user data. Note that component carriers (CCs) allocated to mobile station **100** in the radio base station **200** and scheduling information are reported to the mobile station **100** through the L**1**/L**2** control channels.

On the uplink, a PUSCH, which is used by each mobile station **100** on a shared basis, and a PUCCH, which is an uplink control channel, are used. User data is transmitted by means of this PUSCH. Also, downlink radio quality information (CQI: Channel Quality Indicator) and so on are transmitted by the PUCCH.

FIG. **18** is a block diagram to show a configuration of the radio base station **200** according to the present embodiment. FIG. **19** is block diagram to show a configuration of an antenna section **230**. FIG. **20** is a block diagram to show a configuration of the mobile station **100** according to the present embodiment. Note that the configurations of the radio base station **200**, antenna section **230** and mobile station **100** shown in FIG. **18** to FIG. **20** are simplified to explain the present invention, and are assumed to have configurations which a radio base station, an antenna section and a mobile station should normally have.

The radio base station **200** shown in FIG. **18** has, for example, cell control section #**1** (hereinafter referred to as the "first cell control section") that controls the radio communication in the first cell in a two-cell configuration (for example, the inner cell), cell control section #**2** (hereinafter referred to as the "second cell control section") that controls the radio communication in the second cell (for example, the outer cell), and an antenna section **230** that outputs the beams to form each cell. As described above, the radio base station **200** according to the present embodiment is not limited to a two-cell configuration, and may assume configurations with three or more cells. Assume that, in the case of a configuration with three or more cells, additional control sections such as a third cell control section and more can be provided in addition to the first cell control section and the second cell control section. Note that the radio base station **200** shown in FIG. **18** is a radio base station that controls the vertical plane beam width of each cell as described above.

First, the method of controlling the vertical plane beam width will be described. The radio base station **200** has a communication capacity information acquiring section **231** that acquires information about the communication capacity of each cell (for example, the proportion of connecting user terminals in each cell). The communication capacity information acquiring section **231** can acquire information about the number of user terminals present in each cell based on, for example, system information reported from a higher station apparatus and so on.

To be more specific, the communication capacity information acquiring section **231** acquires information about the number of user terminals that are present in each cell, and then converts the acquired information into data of the proportion of connecting user terminals connected to each cell. Note that the communication capacity information acquiring section **231** can acquire the number of user terminals to be connected to each cell in various other methods besides actually counting the number of user terminals that connect with each cell and perform radio communication. For example, the number of user terminals present in each cell may be calculated based on the assumption that the user terminals are distributed evenly over the area where each cell is formed. Also, it is equally possible to apply, as information about the number of user terminals, statistics given by calculating and processing the number of user terminals statistically, values given by calculating the number of user terminals taking into account the conditions of design of the radio base stations (for example, the place where each cell is formed, and so on), or values given by predicting the number of user terminals from past statistics, system simulations and so on.

The offset amount determining section **232** determines the offset values for changing the vertical plane beam widths of the beams forming the inner cell and the outer cell, based on the information acquired in the communication capacity information acquiring section **231**. To be more specific, the offset amount determining section **232** determines the vertical plane beam widths and/or the transmission power offset values of the beams forming each cell based on the proportion of connecting user terminals in each cell, on a per cell basis, and outputs the determined offset values to a vertical weight generating section **233**.

Also, the offset amount determining section **232** may prepare various combinations of amounts of offset in a database and determine predetermined offset values in accordance with the proportion of connecting user terminals in each cell. The database to define the amount of offset may be built based on information that has been acquired earlier in other radio base stations or values that are calculated based on simulation.

The vertical weight generating section **233** generates vertical weights (phase and amplitude) to apply in the antenna section **230**, based on the offset values determined in the offset amount determining section **232**. The vertical weights generated in the vertical weight generating section **233** are output to the antenna section **230**, and, in the antenna section **230**, transmission signals are multiplied by the weights, thereby controlling the vertical plane beam widths of the beams to be output from the antenna section **230**.

Note that, when controlling transmission power, too, it is equally possible to control the transmission power of the beams to output, based on the power offset values that are determined in the offset amount determining section **232** based on the information acquired in the communication capacity information acquiring section **231**. Similarly, when controlling resource allocation, too, a scheduler may control the resources to allocate to each cell based on the information acquired in the communication capacity information acquiring section **231**.

Although FIG. **18** shows a configuration to provide a communication capacity information acquiring section **231**, an offset amount determining section **232**, and a vertical weight generating section **233** for each of the first cell control section and the second cell control section, this is by no means limiting. A configuration may be possible in which at least one of the communication capacity information acquiring section **231**, the offset amount determining section **232**, and the vertical weight generating section **233** (for example, the communication capacity information acquiring section **231** and the offset amount determining section **232**) is provided for control sections for a plurality of cells (in FIG. **18**, the first cell control section and the second cell control section) on a shared basis.

Next, control of transmitting/received data will be described. In the radio base station **200** shown in FIG. **18**, a scheduler, which is not shown, determines the number of users to multiplex (the number of users multiplexed) based on channel estimation values given from channel estimation sections **215** #**1** to **215** #K, which will be described later. Then, the content of uplink and downlink resource allocation (scheduling information) for each user is determined, and transmission data #**1** to #K for users #**1** to #K are output to corresponding channel coding sections **201** #**1** to **201** #K.

The transmission data is subjected to channel coding in channel coding sections **201** #**1** to **201** #K, and, after that, output to data modulation sections **202** #**1** to **202** #K and subjected to data modulation. At this time, the channel coding and data modulation are executed based on channel coding rates and modulation schemes given from MIMO switching sections **221** #**1** to **221** #K, which will be described later. Transmission data #**1** to #K subjected to data modulation in data modulation sections **202** #**1** to **202** #K are converted from time sequence signals to frequency domain signals through a discrete Fourier transform in an unillustrated discrete Fourier transform section, and output to a subcarrier mapping section **203**.

The subcarrier mapping section **203** maps transmission data #**1** to #K to subcarriers in accordance with resource allocation information given from a resource allocation control section **220**, which will be described later. At this time, the subcarrier mapping section **203** maps (multiplexes) reference signals #**1** to #K input from an unillustrated reference signal generating section and broadcast information and system information input from a broadcast information generating section and a system information generating section, to subcarriers, with transmission data #**1** to #K. In this way, transmission data #**1** to #K mapped to the subcarriers are output to precoding multiplication sections **204** #**1** to **204** #K.

Precoding multiplication sections **204** #**1** to **204** #K apply a phase and/or amplitude shift to transmission data #**1** to #K, for each of antenna elements #**1** to #N, based on precoding weights given from a precoding weight control section **219**, which will be described later (weighting of antenna elements #**1** to #N by precoding). Transmission data #**1** to #K, to which a phase and/or amplitude shift has been applied by precoding multiplication sections **204** #**1** to **204** #K, are output to a multiplexer (MUX) **205**.

In the multiplexer (MUX) **205**, transmission data #**1** to #K, having been subjected to a phase and/or amplitude shift, are synthesized to generate transmission signals for each of antenna elements #**1** to #N. The transmission signals generated in the multiplexer (MUX) **205** are converted from frequency domain signals to time domain signals through an inverse fast Fourier transform in inverse fast Fourier transform sections (IFFT) **206** #**1** to **206** #N. Then, after CPs are added in cyclic prefix (CP) adding sections **207** #**1** to **207** #N, the signals are output to the antenna section **230**.

Meanwhile, transmission signals that are transmitted from the mobile station **100** on the uplink are received in the antenna section **230**, and converted from radio frequency signals into baseband signals through frequency conversion. The baseband signals subjected to frequency conversion have the CPs removed in CP removing sections **211** #**1** to **211** #N, and output to fast Fourier transform sections (FFT sections) **212** #**1** to **212** #N.

FFT sections **212** #**1** to **212** #N perform a Fourier transform of the input received signals, and convert the signals from time sequence signals to frequency domain signals. The received signals having been converted to frequency domain signals are output to data channel signal separation sections **214** #**1** to **214** #K.

Data channel signal separation sections **214** #**1** to **214** #K separate the received signals input from FFT sections **212** #**1** to **212** #N, by, for example, minimum mean squared error (MMSE) and maximum likelihood detection (MLD) signal separation methods. By this means, the received signals having arrived from the mobile station **100** are separated into received signals pertaining to user terminal #**1** to user terminal #K.

Channel estimation sections **215** #**1** to **215** #K estimate channel states from the reference signals included in the received signals separated in data channel signal separation sections **214** #**1** to **214** #K, and report the estimated channel states to control channel demodulation sections **216** #**1** to **216** #K.

The received signals pertaining to user terminal #**1** to user terminal #K, separated in data channel signal separation sections **214** #**1** to **214** #K, are demapped in an unillustrated subcarrier demapping section and converted back to time sequence signals, and then demodulated in data demodulation sections **217** #**1** to **217** #K.

Control channel demodulation sections **216** #**1** to **216** #K demodulate the control channel signals (for example, the PUCCH) included in the received signals separated in data channel signal separation sections **214** #**1** to **214** #K. At this time, in control channel demodulation sections **216** #**1** to **216** #K, the control channel signals corresponding to user terminal #**1** to user terminal #K are demodulated based on the channel states reported from channel estimation sections **215** #**1** to **215** #K. The control channel signals demodulated in control channel demodulation sections **216** #**1** to **216** #K are output to CSI information updating sections **218** #**1** to **218** #K.

CSI information updating sections **218** #**1** to **218** #K extract channel state information (CSI) included in each control channel signal (for example, the PUCCH) or shared data channel signal (PUCCH) input from control channel demodulation sections **216** #**1** to **216** #K, so that CSI is always updated to the latest state. For example, the CSI includes PMIs, RIs and CQIs.

The CSI information updated in CSI information updating sections **218** #**1** to **218** #K is output to the precoding weight control section **219**, the resource allocation control section **220** and MIMO switching sections **221** #**1** to **221** #K.

Based on beam selection information and the CSI information input from CSI information updating sections **218** #**1** to **218** #K, the precoding weight control section **219** generates precoding weights to represent the amounts of phase and/or amplitude shift for transmission data #**1** to #K. The generated precoding weights are output to precoding multiplication sections **204** #**1** to **204** #K, and are used in the precoding of transmission data #**1** to transmission data #K.

Based on the CSI information input from CSI information updating sections **218** #**1** to **218** #K, the resource allocation control section **220** determines the resource allocation information to allocate to each user.

MIMO switching sections **221** #**1** to **221** #K select the MIMO transmission schemes to use for transmission data #**1** to transmission data #K, based on the CSI information input from CSI information updating sections **218** #**1** to **218** #K. Then, the channel coding rates and modulation schemes for transmission data #**1** to transmission data #K to match the selected MIMO transmission schemes are determined. The determined channel coding rates are output to channel coding sections **201** #**1** to **201** #K, and the determined modulation schemes are output to the data modulation sections **202** #**1** to **202** #K.

Next, the configuration of the antenna section **230** will be described with reference to FIG. **19**. The antenna section **230** has a plurality of antenna elements **250**, an RF phase/amplitude adjusting circuit **249**, and a vertical weight multiplication section **240**, and so on.

In the antenna section **230**, signals that are output from the CP adding sections **207** of the first cell control section and the second cell control section are input in the vertical weight multiplication section **240**. Also, information about the vertical weights generated in the vertical weight generating sections **233** of the first cell control section and the second cell control section is also input in the vertical weight multiplication section **240**.

In the vertical weight multiplication section **240**, signals from the first cell control section and the second cell control section are branched via dividers **241** #**1** and **241** #**2**, and are output to phase/amplitude adjustors **243** corresponding to each of a plurality of antenna elements **250**. The vertical weight multiplication section **240** multiplies the vertical weights so that the offset values (here, vertical plane beam width offset values) determined in the offset amount determining section **232** are implemented, in the phase/amplitude adjustors **243**.

The transmission signals in the first cell (for example, the inner cell) and the second cell (for example, the outer cell), output from the vertical weight multiplication section **240**, are synthesized in a synthesizer **244** and then output to the RF phase/amplitude adjusting circuit **249** via a DA converter **245**, an up-converter **246**, and a duplexer **247**. The RF phase/amplitude adjusting circuit **249** adjusts the directions of the beams to form the first cell and the second cell, and furthermore carries out calibration between the branches. Signals output from the RF phase/amplitude adjusting circuit **249** are output via the antenna elements **250**.

Meanwhile, transmission signals transmitted from the mobile station **100** on the uplink are received in antenna elements **250**, and then output to the duplexer **247** via the RF phase/amplitude adjusting circuit **249**. The transmission signals are separated into the transmitting path and the receiving path in the duplexer **247**, and then output to a divider **252** via a down-converter **248** and an AD converter **251**. In the divider **252**, the signals are branched into the signals of the first cell and the second cell, and then output to synthesizers **242** #**1** and **242** #**2** via the phase/amplitude adjustors **243** of the vertical weight multiplication section **240**. In synthesizers **242** #**1** and **242** #**2** of the vertical weight multiplication section **240**, the received signals received in the antenna elements **250** are synthesized for each of the first cell and the second cell, and output to the first cell control section and the second cell control section.

Next, the configuration of the mobile station **100** will be described with reference to FIG. **20**. In the mobile station **100** shown in FIG. **20**, transmission signals output from the radio base station **200** are received by transmitting/receiving antennas TRX #**1** to TRX #N, separated into the transmitting path and the receiving path in duplexers **101** #**1** to **101** #N, and then output to RF receiving circuits **102** #**1** to **102** #N. Then, in RF receiving circuits **102** #**1** to **102** #N, the radio frequency signals are converted into baseband signals through frequency conversion. The baseband signals have the CPs removed in cyclic prefix (CP) removing sections **103** #**1** to **103** #N, and are output to fast Fourier transform sections (FFT sections) **104** #**1** to **104** #N. A receiving timing estimation section **105** estimates the receiving timing from the reference signals included in the received signals, and reports the estimated results to CP removing sections **103** #**1** to **103** #N. FFT sections **104** #**1** to **104** #N perform a Fourier transform on the received signals that are received as input, and convert the time sequence signals into frequency domain signals. The received signals, having been converted into frequency domain signals, are output to a data channel signal separation section **106**.

The data channel signal separation section **106** separates the received signals input from FFT sections **104** #**1** to **104** #N by, for example, minimum mean square error (MMSE) and maximum likelihood detection (MLD) signal separation methods. By this means, the received signals that have arrived from the radio base station **200** are separated into received signals pertaining to user terminal #**1** to user terminal #K, and the received signal pertaining to the user of the mobile station **100** (here, user K) is extracted. A channel estimation section **107** estimates the channel states from the reference signals included in the received signals separated in the data channel signal separation section **106**, and reports the estimated channel states to a control channel demodulation section **108**.

The received signal pertaining to user terminal #K, separated in the data channel signal separation section **106**, is demapped in a subcarrier demapping section, which is not shown, converted back to a time sequence signal, and then demodulated in a data demodulation section **109**. Then, as channel decoding is executed in a channel decoding section, which is not shown, transmission signal #K is reconstructed.

The control channel demodulation section **108** demodulates the control channel signal (for example, the PDCCH) included in the received signal separated in the data channel signal separation section **106**. When this takes place, the control channel demodulation section **108** demodulates the control channel signal corresponding to user terminal #K, based on the channel state reported from the channel estimation section **107**. The control channel signals demodulated by the control channel demodulation section **108** are output to a channel quality measurement section **110**.

The channel quality measurement section **110** measures channel quality (CQIs) based on the control channel signals received as input from the control channel demodulation section **108**. Also, the channel quality measurement section **110** selects PMIs and RIs based on the measured CQIs. Then, CSI (CQIs, PMIs and RIs) or RSRP is reported to a CSI feedback signal generating section **111** and a MIMO switching section **112**.

In the CSI feedback signal generating section **111**, CSI feedback signals to feed back to the radio base station **200** are generated. In this case, the CQIs, PMIs and RIs reported from the channel quality measurement section **110** are included in the CSI feedback signals. The feedback signals (CSI feedback or RSRP feedback) generated in the CSI feedback signal generating section **111** are output to a multiplexer (MUX) **113**.

Based on the CQIs, PMIs and RIs input from the channel quality measurement section **110**, the MIMO switching section **112** selects the MIMO transmission scheme to use for transmission data #K. Then, the channel coding rate and modulation scheme for transmission data #K, to match the selected MIMO transmission scheme, are determined. The determined channel coding rates are output to a channel coding section **114**, and the determined modulation schemes are output to a data modulation section **115**.

Meanwhile, transmission data #K pertaining to user #K, transmitted from a higher layer, is subjected to channel coding by the channel coding section **114**, and then subjected to data modulation in the data modulation section **115**. Transmission data #K, having been subjected to data modulation in the data modulation section **115**, is converted from a time sequence signal to a frequency domain signal in a serial-to-parallel conversion section, which is not shown, and output to a subcarrier mapping section **116**.

The subcarrier mapping section **116** maps transmission data #K to subcarriers in accordance with schedule information that is designated from the radio base station **200**. At this time, the subcarrier mapping section **116** maps (multiplexes) reference signal #K, generated in a reference signal generating section (not shown), to the subcarriers with transmission data #K. Transmission data #K mapped to subcarriers in this way is output to a precoding multiplication section **117**.

The precoding multiplication section **117** applies a phase and/or amplitude shift to transmission data #K, for each of transmitting/receiving antennas TRX #**1** to TRX #N. Then, the precoding multiplication section **117** applies a phase and/or amplitude shift in accordance with the precoding weights that correspond to the PMIs that are designated by the control channel signals demodulated in the control channel demodulation section **108**. Transmission data #K, having been subjected to a phase and/or amplitude shift by the precoding multiplication section **117**, is output to the multiplexer (MUX) **113**.

The multiplexer (MUX) **113** synthesizes transmission data #K, to which a phase and/or amplitude shift has been applied, with the control signals generated in the CSI feedback signal generating section **111**, and generates transmission signals for each of transmitting/receiving antennas TRX #**1** to TRX #N. The transmission signals generated in the multiplexer (MUX) **113** are converted from frequency domain signals to time domain signals through an inverse fast Fourier transform in inverse fast Fourier transform sections **118** #**1** to **118** #N, and then have CPs added in CP adding sections **119** #**1** to **119** #N, and are output to RF transmitting circuits **120** #**1** to **120** #N. Then, after the frequency conversion process into a radio frequency band is executed in RF transmitting circuits **120** #**1** to **120** #N, the signals are output to transmitting/receiving antennas TRX #**1** to TRX #N via duplexers **101** #**1** to **101** #N, and output from transmitting/receiving antennas TRX #**1** to TRX #N to the radio base station **200** on the uplink.

Note that the configurations of the radio base station **200** that are applicable with the present embodiment are not limited to the configuration shown in above FIG. **18**. Similarly, the configuration of the antenna section **230** is also not limited to the configuration shown in FIG. **19**. As other configurations, a configuration may be possible in which the vertical weight multiplication section **240** is provided in the inner cell control section and the outer cell control section. Examples of the configurations of the radio base station **200** and the antenna section **230** in this case will be described with reference to FIG. **21** to FIG. **23**. Note that descriptions of parts that overlap with above FIG. **18** and FIG. **19** will be omitted.

The radio base station **200** shown in FIG. **21** has transmitting vertical weight multiplication sections **236** #**1** to #K that multiply transmitting/received signals by vertical weights in the first cell control section and the second cell control section, and receiving vertical weight multiplication sections **235** #**1** to #K.

In the first cell control section and the second cell control section of the radio base station **200**, vertical weights that are generated in the vertical weight generating section **233** are controlled in a weight switching section **234**, and output to transmitting vertical weight multiplication sections **236** #**1** to #K and receiving vertical weight multiplication sections **235** #**1** to #K. The weight switching section **234** controls and switches between a plurality of weights output from the vertical weight generating section **233** per predetermined period, and outputs the vertical weights generated in the vertical weight generating section **233** to transmitting vertical weight multiplication sections **236** #**1** to #K and receiving vertical weight multiplication sections **235** #**1** to #K.

For example, as shown in above FIG. **11** to FIG. **15** and so on, when time allocation control is applied, when the vertical plane beam width and tilt angle of each cell are changed per predetermined period, the control is executed in the weight switching section **234**. To be more specific, from the data of the proportion of user terminals connected to each cell generated in the communication capacity information acquiring section **231** and the offset values determined in the offset amount determining section **232**, the weight switching section **234** determines the length of time to allocate to t_1 and t_2 or to t_3 and t_4 such that resources are allocated adequately (for example, evenly) to each user terminal. Also, the weight switching section **234** designs control such that, together with each user terminal's scheduling information allocated in the subcarrier mapping section **203**, and in coordination with the passage of the above time period, a plurality of weights output from the vertical weight generating section **233** are switched and output to transmitting vertical weight multiplication sections **236** #**1** to #K.

Furthermore, information about the transmission timing of the mobile station and so on determined based on the length of time allocated to t_1 and t_2 or to t_3 and t_4, is reported from the radio base station to the mobile station by means of broadcast information. Each user terminal receives the signals transmitted from the radio base station normally, and, meanwhile, as for the transmission timing, controls the transmission schedule in accordance with the transmission timing reported from the radio base station by means of broadcast information. The radio base station then designs control such that, in coordination with the above time period, a plurality of weights output from the vertical weight generating section **233** are switched and output to receiving vertical weight multiplication sections **235** #**1** to #K, thereby receiving the signals from each mobile station with coordinated timing.

FIG. **22** shows a block diagram of the transmitting vertical weight multiplication section **236**. In the transmitting vertical weight multiplication section **236**, signals output from the precoding multiplication section **204** are branched in a divider **261**, and output to phase/amplitude adjustors **263** corresponding to a plurality of antenna elements **250**. In the phase/amplitude adjustors **263**, weights that are generated in the vertical weight generating section **233** are multiplied on the signals. After the signals output from the FFT section **212** are adjusted in a phase/amplitude adjustor **264**, the receiving vertical weight multiplication section **235** synthesizes these in a synthesizer **262**, and output the result to a data channel signal separation section **214**. Note that, when a vertical weight multiplication section is provided in the first cell control section and the second cell control section, the antenna section **230** may assume a configuration removing the vertical weight multiplication section **240** from the configuration shown in FIG. **19**, as shown in FIG. **23**.

Now, although the present invention has been described in detail with reference to the above embodiment, it should be obvious to a person skilled in the art that the present invention is by no means limited to the embodiment described herein. For example, the number of users and the number of processing sections in the devices in the above-described embodiment are by no means limiting, and it is equally possible to change these as appropriate depending on device configurations. The present invention can be implemented with various corrections and in various modifications, without departing from the spirit and scope of the present invention defined by the recitations of the claims. Consequently, the descriptions herein are provided only for the purpose of explaining examples, and should by no means be construed to limit the present invention in any way.

The disclosure of Japanese Patent Application No. 2012-081085, filed on Mar. 30, 2012, including the specification, drawings, and abstract, is incorporated herein by reference in its entirety.

The invention claimed is:

1. A radio communication method for a radio base station that outputs a plurality of beams of varying tilt angles and forms a plurality of cells in a vertical direction, and a user terminal that establishes wireless connection with the radio base station, the radio communication method comprising the steps in which:

the radio base station:

acquires information about communication capacity of each of the plurality of cells; and

sets the amount of resources to allocate to a cell having lower communication capacity among the plurality of cells lower than for a cell having higher communication capacity,

wherein the radio base station makes at least one of a frequency range to allocate resources to the call having lower communication capacity among the plurality of cells and a time period to allocate resources, narrower than for the cell having higher communication capacity,

wherein the radio base station provides a time period to allocate resources to the cell having higher communication capacity and not allocate resources to the cell having lower communication capacity, and, in the time period, increases the transmission power of the cell having higher communication capacity, and

wherein, in the time period, the radio base station changes a tilt angle of the beam forming the cell having higher communication capacity so that a coverage area of the cell having higher communication capacity expands in a direction of the coverage area of the cell having lower communication capacity formed outside the time period.

2. A radio communication method for a radio base station that outputs a plurality of beams of varying tilt angles and forms a plurality of cells in a vertical direction, and a user terminal that establishes wireless connection with the radio base station, the radio communication method comprising the steps in which:

the radio base station:

acquires information about communication capacity of each of the plurality of cells;

selects a predetermined user terminal that can connect with a cell having lower communication capacity with predetermined quality or above, among user terminals that are present in a coverage area of a cell having higher communication capacity among the plurality of cells; and

provides a time period to allocate resources to the cell having lower communication capacity and not allocate resources to the cell having higher communication capacity, and, in the time period, allocate resources to the predetermined user terminal from the cell having lower communication capacity,

wherein, in the time period, the radio base station changes at least one of a tilt angle and a vertical plane beam width of a beam to form the cell having lower communication capacity so that a coverage area of the cell having lower communication capacity expands in a direction of the coverage area of the cell having higher communication capacity formed outside the time period.

3. A radio base station that forms a plurality of cells in a vertical direction, the radio base station comprising:

an antenna section configured to output a plurality of beams of varying tilt angles and form a plurality of cells;

an information acquiring section configured to acquire information about communication capacity of each of the plurality or cells; and

a control section configured to set the amount of resources to allocate to a cell having lower communication capacity among the plurality of cells lower than for a cell having higher communication capacity,

wherein the control section makes at least one of a frequency range to allocate resources to the cell having lower communication capacity among the plurality of cells and a time period to allocate resources, narrower than for the cell having higher communication capacity,

wherein the control provides a time period to allocate resources to the cell having higher communication capacity and not allocate resources to the cell having lower communication capacity, and, in the time period, increases the transmission power of the cell having higher communication capacity,

wherein, in the time period, the control section changes a tilt angle of the beam forming the cell having higher communication capacity so that a coverage area of the cell having higher communication capacity expands in a direction of the coverage area of the cell having lower communication capacity formed outside the time period.

4. A radio communication system comprising a radio base station that forms a plurality of cells in a vertical direction and a user terminal that establishes wireless connection with the radio base station, wherein the radio base station comprises:

an antenna section configured to output a plurality of beams of varying tilt angles and form a plurality of cells;

an information acquiring section configured to acquire information about communication capacity of each of the plurality of cells; and

a control section configured to set the amount of resources to allocate to a cell having lower communication capacity among the plurality of cells lower than for a cell having higher communication capacity,

wherein the control section makes at least one of a frequency range to allocate resources to the cell having lower communication capacity among the plurality of cells and a time period to allocate resource, narrower than for the cell having higher communication capacity,

wherein the control section provides a time period to allocate to the cell having higher communication capacity and not allocate resources to the cell having lower communication capacity, and, in the time period, increases the transmission power of the cell having higher communication capacity,

wherein, in the time period, the control section changes a tilt angle of the beam forming the cell having higher communication capacity so that a coverage area of the cell having higher communication capacity expands in a direction of the area of the cell having lower communication capacity formed outside the time period.

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